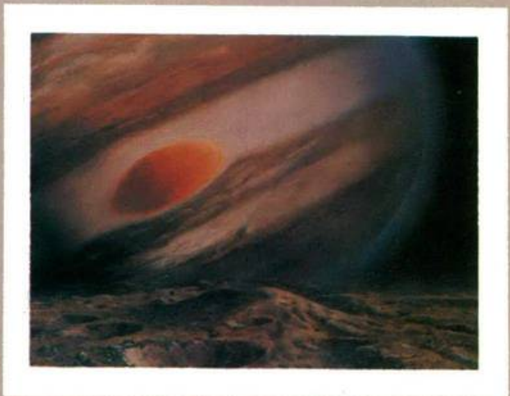
ASTRONOMY

AUGUST 1977 $1.50

NEW FROM

To you, our readers, ASTRONOMY now offers a series of 8 dynamic, new, full color Art Reprints of some of the best paintings — by artists John Clark, Victor Costanzo, James Hervat, Mark Paternostro, Adolf Schaller and Rick Sternbach — that have appeared in ASTRONOMY Magazine.

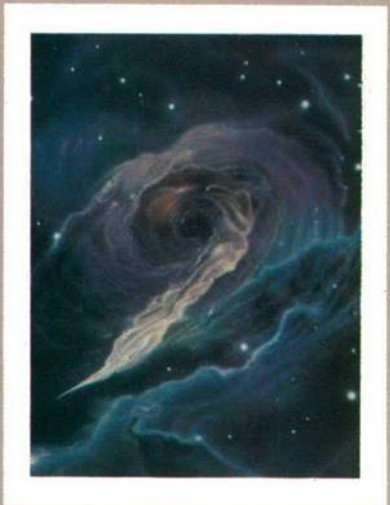
Adding to the drama, depth and realism of each piece, these Art Reprints are printed on 80 lb. linen finish paper, and are coated with a high gloss varnish. And each reprint is surrounded with a one inch white border,



Actual Size 17" x 22"

Jupiter From Io

This dramatic painting reveals an incredible vista that man may never witness first hand: the incredible bulk of Jupiter looming over the surface of its satellite Io. Located deep within Jupiter's intense magnetic field, Io is one of the most lethal places in the entire solar system. To view this scene, we must rely on the imagination of artist John Clark.



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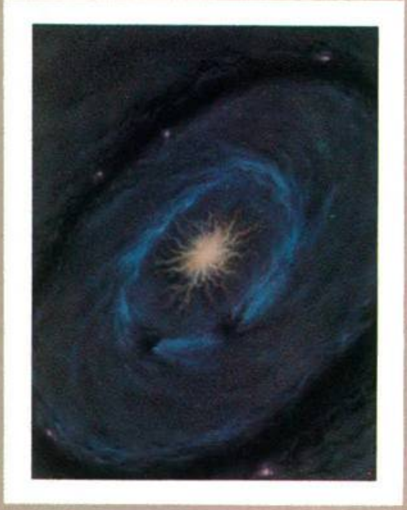
Black Hole

A nearly invisible small black hole speeds through a dense interstellar cloud of gas and dust, leaving behind a trail of gravitationally disturbed material. The infalling material becomes hot and emits light as it drains out of the known universe. Artist Mark Paternostro speculates on the appearance of these still undetected objects.



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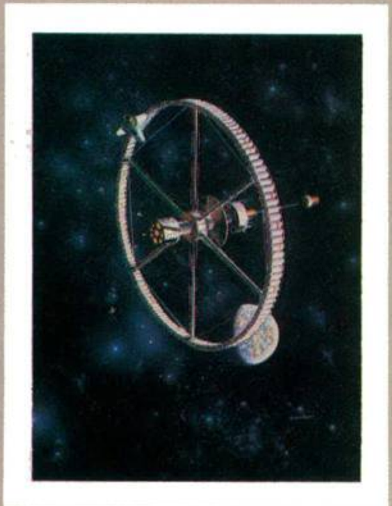
The Galactic Core

The nucleus of our galaxy is one of the true unknowns in our universe. Recent radio and infrared observations suggest that two titanic swirling rings of gas and dust occupy the core of our galaxy. These rings were apparently produced by an explosion 10 million years ago. Victor Costanzo's painting indicates that actual conditions at the galaxy's center remain a mystery.



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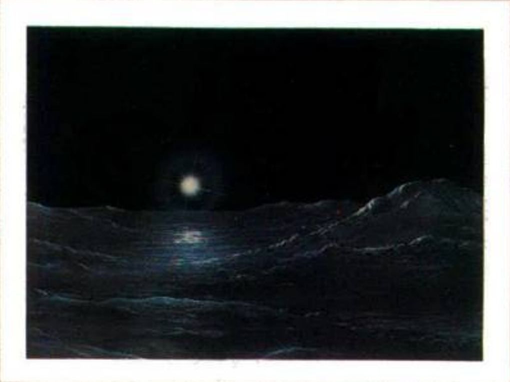
Colony in Space

What will space stations and orbiting colonies of the future look like? Artist Rick Sternbach provides an ingenious answer in his painting of a mile wide space station wheeling slowly above the gibbous Earth. Shuttle rockets near the station's hub bring ore from the lunar surface for refinement in the station's zero gravity manufacturing center.



Actual Size 17" x 22"

Pluto

The setting sun glints off a low plain of methane ice on the surface of the smallest and most distant planet, Pluto. The cold and forbidding scene — completely alien to Earth dwellers — comes to life in this rendition by James Hervat. The mysteries of Pluto are brought home to us as we stand and gaze back toward our incredibly distant sun.

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making it easier to frame, or suitable for hanging as is.

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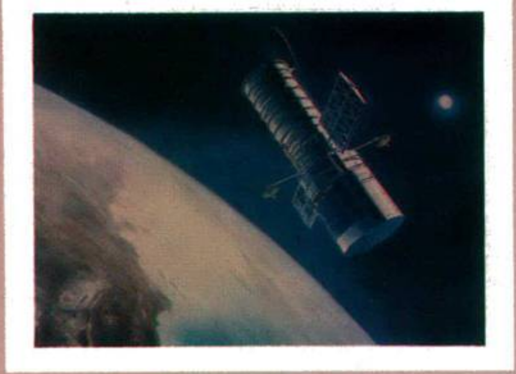

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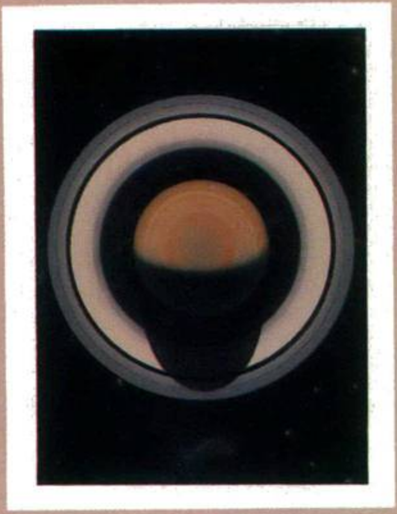
Space Telescope

Painted by John Clark from official NASA blueprints, this poster depicts the Space Telescope — a powerful 94 inch (2.4 meter) aperture telescope due to be launched during the early 1980s by NASA's Space Shuttle. This is an accurate depiction of an instrument that will revolutionize man's view of the universe during the decades it remains in operation.



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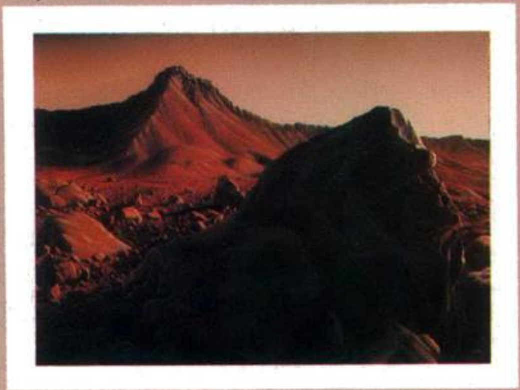
Saturn

In an unusual perspective from above the north pole of Saturn, we can identify the planet's three main rings and their sizes relative to Saturn itself, enabling us to grasp the vast extent of Saturn's ring system. This remarkable painting by Adolf Schaller gives us a view of the planet not obtainable from Earth.

Vallis Marineris

Photographs returned from Mariner and Viking probes revealed for the first time the immensity of Vallis Marineris, the equatorial canyon of Mars. This painting by Adolf Schaller — meticulously transcribed from overhead Viking photos — takes us to the foot of a blanket of landslide rubble in the canyon itself.



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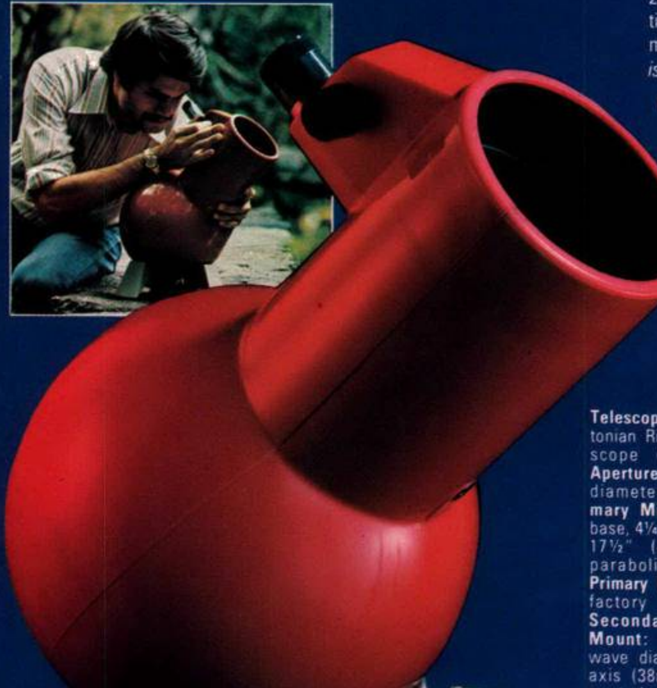

Take It Anywhere — Use It Anywhere!

The 2001 weighs just over 10 pounds and is only 17 inches long. It can set up in seconds. Anyone, even young children, can use it easily.

Its 4¼" diameter parabolic primary mirror is precision polished to a tolerance of ⅛ wave. A ⅛ wave diagonal mirror supported from an optical quality coated window and a 28 mm focal length compound, achromatic eyepiece complete the optical system. Everything is pre-collimated requiring no user adjustments and the system is protected from dust and moisture by the window. The 2001 gives you a 17½ inch objective focal length with an effective magnification power of 16X. *There is no other telescope like it!*

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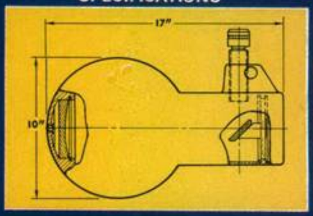
SPECIFICATIONS



Telescope Type: Newtonian Rich Field Telescope (RFT). **Clear Aperture**: 4" (102mm) diameter; f/4.4. **Primary Mirror:** Pyrex* base, 4¼" (108mm) dia. 17½" (445mm) F.L. parabolic ⅛ wave. **Primary Mount**: Fixed, factory collimated. **Secondary Mirror & Mount**: Pre-aligned ⅛ wave diagonal 1½" minor axis (38mm) mounted to coated optical window. **Eyepiece**: 1¼" O.D., 28mm F.L. compound Achromatic. **Power**: 16X with above eyepiece. Other eyepieces or optional Barlow Lens may be used to increase power. **Field of View**: 3.0° with eyepiece supplied. **Focusing**: Smooth, posi-grip, rubber roller focusing (25 feet to infinity). **Telescope Body**: Special, high-impact plastic. **Dimensions**: Length: 17" (432mm); Sphere dia.: 10" (254mm). **Weight**: 8.4 lbs. (3.8kg) without stand. Stand weight 2 lbs. (0.9kg).

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August 1977 Vol. 5, No. 8

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Cover

High in the August sky and easily visible to any telescope user is M-27, the Dumbbell nebula, located in the constellation Vulpecula. The Dumbbell (highlighted in the Close-Up section of Star Dome) is the finest of the class of objects known as planetary nebulae — expanding shells of gas thrown off by small, hot stars in their death throes. This month's Gazer's Gazette is devoted to the observation of these nebulae: where to find them, how to recognize them, and what instruments you'll need to see them. ASTRONOMY this month discusses the possibilities of interstellar travel and how it might be realistically achieved. We speculate on whether or not our universe is only a single component of an endlessly oscillating series, and we continue our series on building your own six inch reflector. Our cover photo is a 45 minute exposure on High Speed Ektachrome, obtained with a cold camera through a Celestron 14 at f/11. Photograph by Leo C. Henzl Jr.

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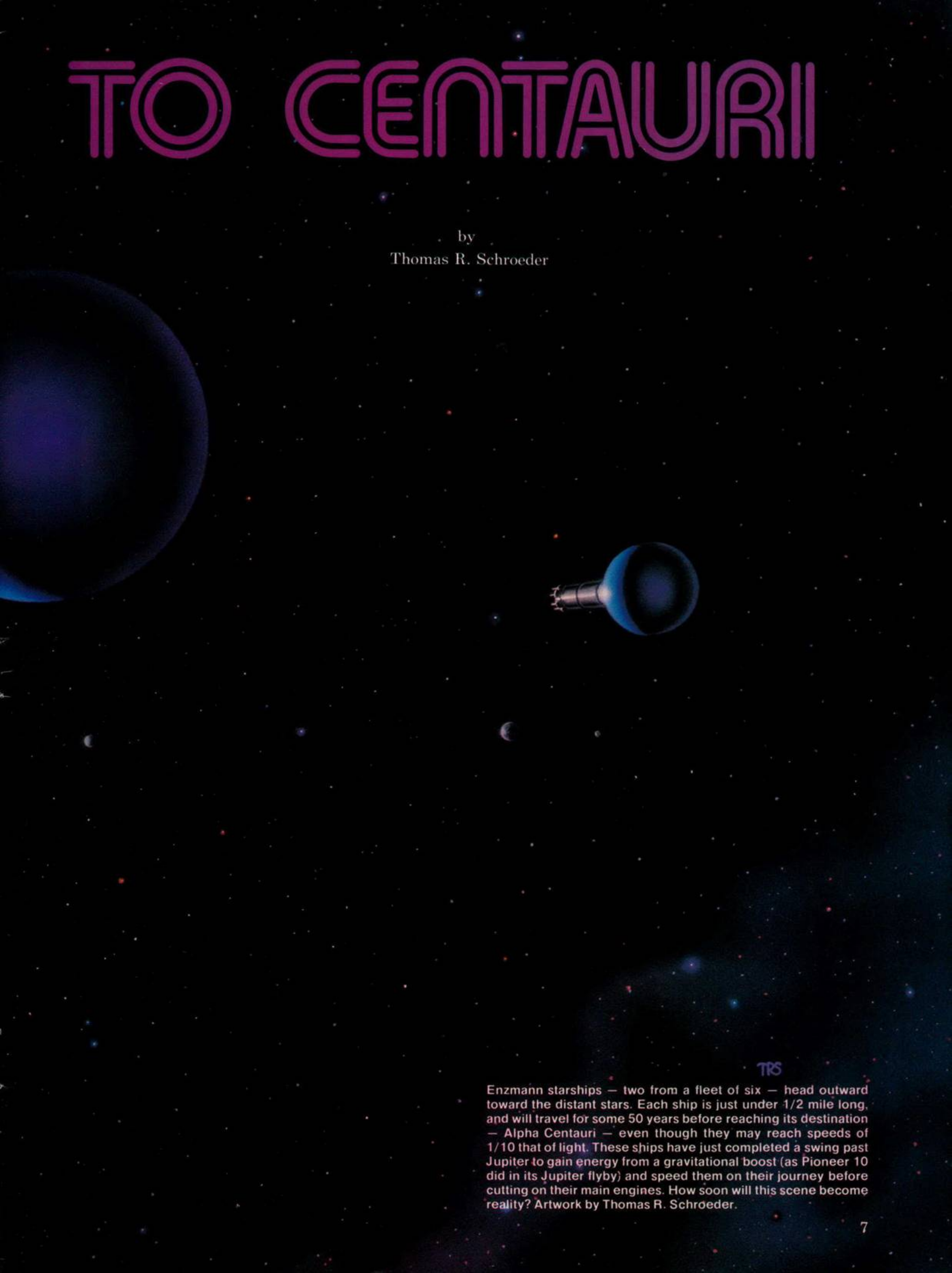
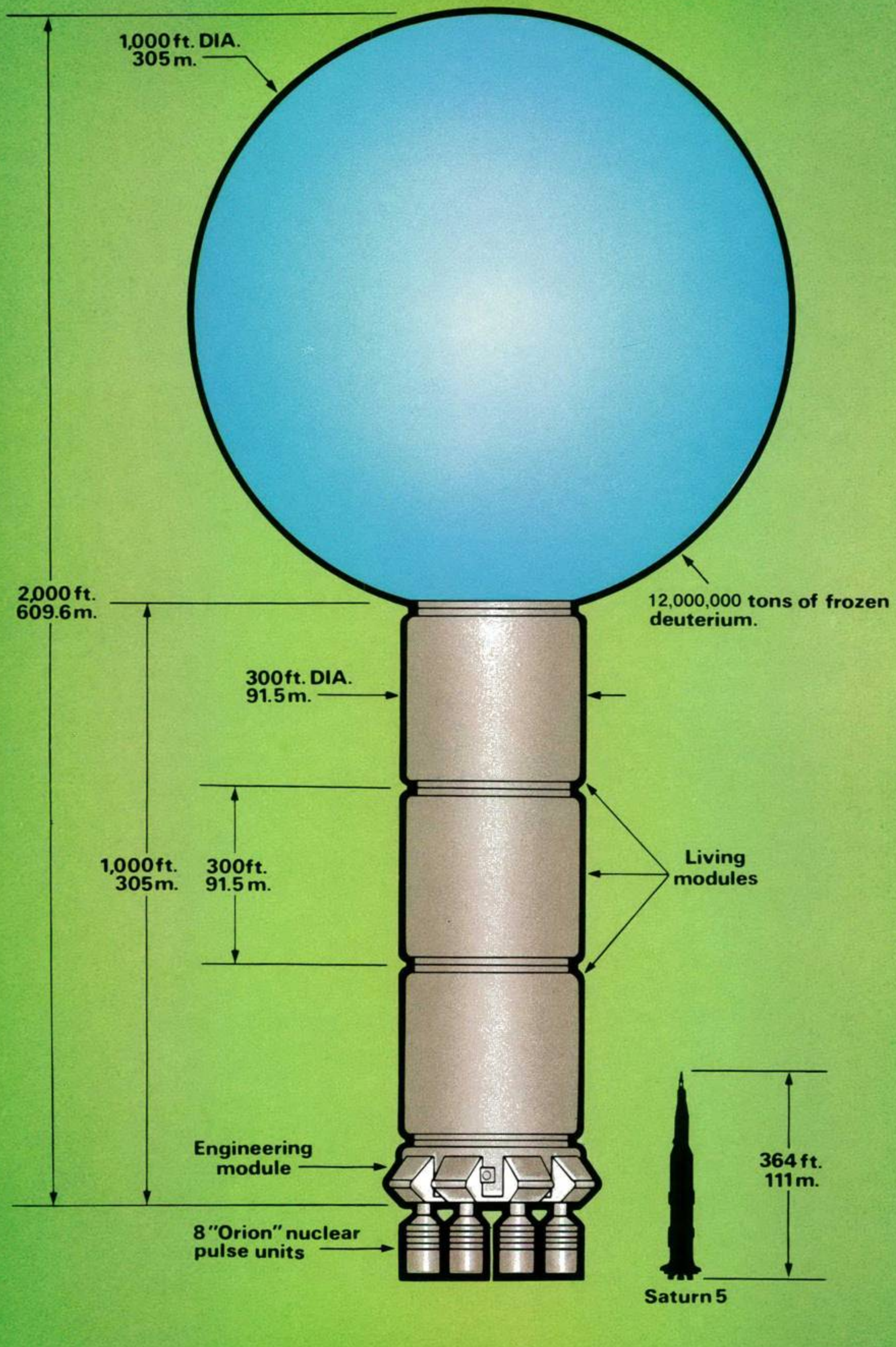
SLOW BOAT

TO CENTAURI

by
Thomas R. Schroeder



Enzmann starships — two from a fleet of six — head outward toward the distant stars. Each ship is just under 1/2 mile long, and will travel for some 50 years before reaching its destination — Alpha Centauri — even though they may reach speeds of 1/10 that of light. These ships have just completed a swing past Jupiter to gain energy from a gravitational boost (as Pioneer 10 did in its Jupiter flyby) and speed them on their journey before cutting on their main engines. How soon will this scene become reality? Artwork by Thomas R. Schroeder.


1,000 ft. DIA.
305 m.
2,000 ft.
609.6 m.
12,000,000 tons of frozen deuterium.
300 ft. DIA.
91.5 m.
1,000 ft.
305 m.
300 ft.
91.5 m.
Living modules
Engineering module
8 "Orion" nuclear pulse units
364 ft.
111 m.
Saturn 5

Enzmann Starship

Travel to the stars is not at all difficult — provided, of course, that you are in no particular hurry. Any object with a launch velocity slightly greater than 20 miles per second, launched in the direction of Earth's motion, will escape from the solar system altogether. In fact, it's possible to get away with less: Pioneer 10 (launched on March 3, 1972) had a launch velocity of about nine miles per second. It gained enough speed as it passed Jupiter in the winter of 1973 to allow its escape into interstellar space. This gives Pioneer 10 the honor of becoming humanity's first piece of interstellar space garbage. Crawling deeper and deeper into the eternal night that yawns before it, the probe will leave the confines of our solar system sometime in 1987 — traveling at a mere seven miles per second. But even if it were headed toward our nearest neighboring star (which it isn't), it would take the better part of 80,000 years to make that journey. The problem is clearly one of sheer distance.

Interstellar distances belong to an entirely different order of magnitude than those between the planets. To illustrate the profound difference, we can look at the width of the known solar system, which can be measured in 11 light-hours. Light traveling at 186,282 miles per second needs 8.3 minutes to span the 93 million miles between the sun and Earth. Those same light photons require 5-1/2 hours to reach Pluto, the outermost planet in the solar system. In contrast, the average distance between stars in our local stellar neighborhood ranges from 24 to 30 trillion miles — gulfs so vast it takes light four to five years to crawl from one star to the next!

Interstellar travel would obviously be much more attractive if stars could be reached within a human's lifespan. But in order for a spacecraft to get from one star to another in a reasonable period of time, it has to move at a substantial fraction of the velocity of light. In 1963, Dr. Edward Purcell, a Nobel Laureate in physics from Harvard University, became one of the first scientists to look seriously into the mathematics of interstellar rocketry. Purcell did so, however, in order to prove that interstellar flight was not only impossible, but that it was totally hogwash. Reasoning that conventional propulsion methods were hopelessly inadequate, Purcell turned to hypothetical power sources to propel his starship.

The second most efficient reaction in the universe is the fusion of four hydrogen nuclei under great pressure to form one helium nucleus. Although it is less than 1/2 percent of the original mass, the energy release is titanic. Nuclear fusion is the energy process that powers the stars.

A slightly less efficient fusion reaction is that used in the hydrogen bomb. In this reaction, hydrogen isotopes such as deuterium (heavy hydrogen — one proton and one neutron) and tritium (heavy-heavy hydrogen — one proton and two neutrons) are combined to form helium.

The Sun's Neighbors
Stars within 12 Light-Years

Name	Distance (light-years)	Spectral Class.	Remarks
Sun (Sol)		G2	Planetary system with known life
Proxima Centauri	4.29	M5e	Nearest star system to our sun, solar type star of high biological interest
Alpha Centauri A	4.38	G2	
Alpha Centauri B	4.38	K6	
Barnard's star	5.91	M5	Evidence for planetary system, unseen companions
Wolf 359	7.57	M8e	
Lalande 21185	8.04	M2	
Sirius A	8.65	A1	White dwarf of high astrophysical interest
Sirius B	8.65	DA	
Luyten 726-8 A	8.94	M6e	
Luyten 726-8 B	8.94	M6e	
Ross 154	9.45	M5e	
Ross 248	10.29	M6e	
Epsilon Eridani	10.69	K2	Cool star of high biological interest
Luyten 789-6	10.80	M6	
Ross 128	10.95	M5	
61 Cygni A	11.17	K5	Cool stars of possible biological interest
61 Cygni B	11.17	K7	
Epsilon Indi	11.21	K5	Cool star of possible biological interest
Procyon A	11.36	F5	
Procyon B	11.36	DF	
Sigma 2398 A	11.48	M4	
Sigma 2398 B	11.48	M5	
Groombridge 34 A	11.57	M2	
Groombridge 34 B	11.57	M4	
Lacaille 9352	11.69	M2	
Tau Ceti	11.95	G8	Nearest single solar type star of high biological interest

To be a home for 200 people for 50 years, an Enzmann starship has to be big! Fuel is stored in the spherical front section; living quarters (internally modularized) occupy the centers. The "bottom" end contains the engines that could push the craft at up to 10 percent the speed of light. Diagram by Thomas R. Schroeder.

For the past 20 years, there has been a worldwide effort to trap the evasive "genie" of nuclear fusion, in order to tap a virtually inexhaustible energy supply. The genie is an apt analogy: Research has primarily been directed toward perfecting a leakproof magnetic "bottle" to contain the superhot plasma, allowing the fuel to fuse and release more energy than the containment process uses. So far, however, creating such a magnetic field has been beyond the capabilities of researchers. Building an open-ended fusion rocket system may prove to be much more difficult than a "simple" system for generating electricity.

Assuming that these present difficulties would eventually be resolved, Purcell calculated that in order for a fusion powered starship to make a round trip at 99 percent of the speed of light, 1.6 billion tons of fuel for each single ton of payload would be required. For example, for a tiny 10 ton capsule to be accelerated at the start of its voyage, halted at its destination, and accelerated and decelerated again on its return flight, 16 billion tons of hydrogen would be required. Since the fuel would also have to be accelerated, the total requirement would be 500 billion, billion, billion, billion tons — a bit uneconomical!

The situation becomes a vicious circle: The rocket must spend a considerable amount of energy just lifting its own propellant mass. Obviously, to remain a reasonable size, fusion powered spacecraft will be able to attain only a few percent of the speed of light.

So, being supremely optimistic, Purcell turned to the hypothetical photonic drive. The pure photon engine is considered the "Holy Grail" of rocketry by most space scientists. Such a drive would convert *all* of its propellant mass into energy and eject a collimated beam of light to propel it at near light velocity. Unfortunately, no one has the slightest idea of how to build one.

In theory, the only fuel source that can generate a 100 percent efficient reaction is antimatter. By contrast, a hydrogen fusion reaction turns only 0.4 percent of the hydrogen's matter into energy!

Antimatter was first predicted theoretically and then verified in 1932 in experiments using cyclotrons, and later, synchrotrons. There is plenty of evidence to support the belief that for every normal type of subatomic particle, there is an antiparticle; when normal matter collides with its antimatter counterpart, each electrically cancels out the other, producing a gigantic release of energy.

For Purcell's purposes, our present methods for producing antimatter are primitive and inefficient, but there is no reason why they should always remain so. A quantity of antimatter could be maintained, in the absence of gravity, by electrostatic fields requiring no physical contact with the ship. The antimatter could be carried in a convenient liquid or solid form; frozen antihydrogen, held at a temperature of a few degrees above absolute zero, makes an excellent candidate. Antihydrogen atoms consist of antiprotons, around which positrons (anti-electrons) would circle. In an energy releasing reaction, equal portions of normal hydrogen and antihydrogen are mixed. Photons emitted during a controlled reaction (in which the hydrogen and antihydrogen annihilate one another) could be beamed backward by a gigantic parabolic reflector, perhaps as much as a mile in diameter. The reflector would also have to be nonmaterial, because if as little as one millionth of the energy reaches the vessel in the form of waste heat, thousands of square miles of radiating surface would be needed for cooling.

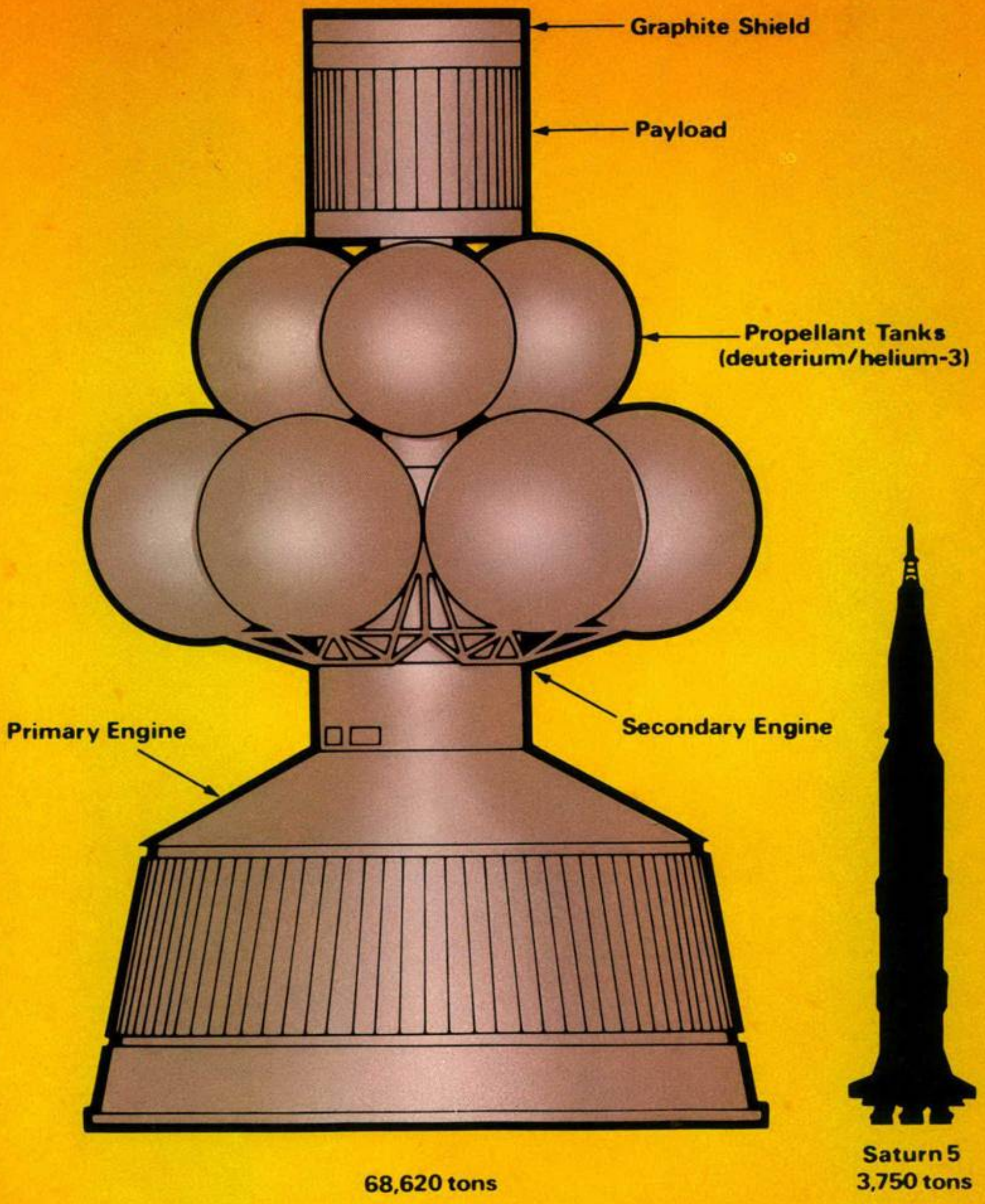
Putting all these engineering problems aside, Purcell calculated that in order for one round trip at 99 percent of the velocity of light, 40,000 tons of fuel, equally divided between matter and antimatter, would be required for every one ton of payload — making the vehicle far smaller than the previously mentioned fusion starship, but still prohibitively large from a practical point of view. Purcell apparently hoped this would put an end to any further discussions of possible starship schemes.

However, not all scientists were so pessimistic about the possibility of interstellar travel. Five years later, Freeman J. Dyson, a theoretical physicist at Princeton University, stated that Purcell's calculations were perfectly valid insofar as they related to fuel requirements for relativistic journeys. He asked, though, what about the slower trips? Dyson went on to design a spaceship capable of delivering a very large payload of 45,000 tons (enough for a small Noah's Ark) to Alpha Centauri in about 130 years. The design utilized a propulsion system that is within the grasp of our present technology: the nuclear-pulse engine. During the period from 1958 to 1965, the concept of the nuclear-pulse rocket and some fundamental research was developed and tested as Project Orion (under the auspices of the United States Air Force). At the time of these feasibility studies, the nuclear-pulse drive was being considered as a possible interplanetary propulsion method. But Project Orion was later shelved in accordance with the Nuclear Test Ban Treaty. Dyson, who worked on Project Orion, later revived the concept for extrasolar travel.

The basic idea was to make use of the shock wave and plasma cloud from a hydrogen bomb explosion. This bizarre design consisted of a series of low yield nuclear explosions at the rear of the space vehicle,

At the Speed of Light . . .

From our sun to:	Miles	Kilometers	Light Distance
Earth	92,870,000	149,450,000	8.3 light-minutes
Mars	142,000,000	228,000,000	12.7 light-minutes
Jupiter	484,000,000	778,700,000	43.3 light-minutes
Saturn	888,000,000	1,428,000,000	1.31 light-hours
Uranus	1,790,000,000	2,872,000,000	2.65 light-hours
Neptune	2,800,000,000	4,500,000,000	4.18 light-hours
Pluto	3,700,000,000	5,900,000,000	5.50 light-hours
Alpha Centauri	25,284,000,000,000	40,457,000,000,000	4.38 light-years



Project Daedalus Star Probe

Man's first interstellar probe might be a starship of the type described by the British Interplanetary Society's Project Daedalus, designed to deliver an unmanned one million pound scientific payload to a nearby star — one way only — on a flyby mission. As the starship reached the target star, it would release its payload — as many as 10 or 20 highly computerized robot explorers — to individual objects within the target star's planetary system. Years later the radioed data from the probes would finally arrive at Earth. The Daedalus starship is a two stage craft, with each stage a nuclear-pulse jet. The main engine, some 400 feet across, will generate power from 250 nuclear explosions per second; when it has accelerated the entire second stage and its fuel supply to a very high speed, the first stage is jettisoned and the second stage takes over without having to push the great bulk of the main engines. It will achieve a final speed of almost 100 million m.p.h. Is it likely that such a ship will be built in our lifetimes? The expense would be enormous; a committment from all of mankind would be required to launch such a probe. Diagram by Thomas Schroeder.

TRS

where a giant *pusher plate* mounted on huge shock absorbers would smooth out the detonations. A rapid fire sequence of blasts could provide nearly uniform thrust. Dyson's design called for 300,000 bombs that weighed six times as much as the payload. By exploding one bomb per second for 10 days, the spacecraft would accelerate at one G, with a resulting final velocity of about three percent the speed of light.

Launching small, self-supporting colonies out across the void is not a new idea. In 1929, J.D. Bernal, a British physicist, first suggested that a flight to the stars could be accomplished by use of huge "interstellar arks". Each ark would carry a closed-cycle balanced ecology, complete with its own flora and fauna. On such artificial worlds, hundreds or even thousands of people would raise crops and tend their herds, sustaining a life-to-death cycle for several hundred years. Upon reaching their destination, the distant descendants of the original pioneers would disembark and colonize.

Since Bernal's idea for the multigeneration starship was first proposed, the design has changed little. In 1952, Dr. L.R. Shepherd (in an article in the journal of the British Interplanetary Society) added some new wrinkles to Bernal's notion by suggesting that artificially hollowed asteroids be used as transport ships. Shepherd forecast the day when most of our solar system will be tamed, making it economically feasible to use mined-out asteroids. All that a future society need do would be to choose a roughly cylindrical chunk of nickel-iron a few miles long, carve it out, make it livable, and add a durable ion drive. Shepherd justified using an ion drive by reasoning that existing chemical and nuclear fission powered rockets were far too weak. The propellant is a metal (one with a low boiling point), and either cesium or cadmium would do nicely. In an ion engine, the fuel is ionized (its electrons stripped away) and vaporized by heat; the metal gas is then accelerated by electric fields. Heat and electricity are provided by nuclear breeder-type reactors. A nuclear-electric rocket could generate a great deal of power from a small quantity of fuel and maintain very high exhaust velocities over long periods of time. On such a long flight, a truly gigantic fuel tank would be needed. Unfortunately, such a rocket has a low thrust ratio, so a trip even to the nearest star would last several centuries.

Shepherd has pointed out that the multigeneration starship concept itself has another flaw: No one has ever built a machine that could function continuously for several centuries. Onboard equipment would have to be continually inspected and repaired, because once in flight the colonists could not send back to Earth for parts.

Converting an asteroid into a starship is standard science fiction fare. Is it also a realistic possibility? While we don't know now, we may within a few generations. Pictured here is an asteroid interstellar ark returning to Earth from a 10 year shakedown cruise before picking up its final crew for an interstellar trip. The glow from the aft end of the ark is caused by high durability ion thrusters. Artwork by Thomas R. Schroeder.

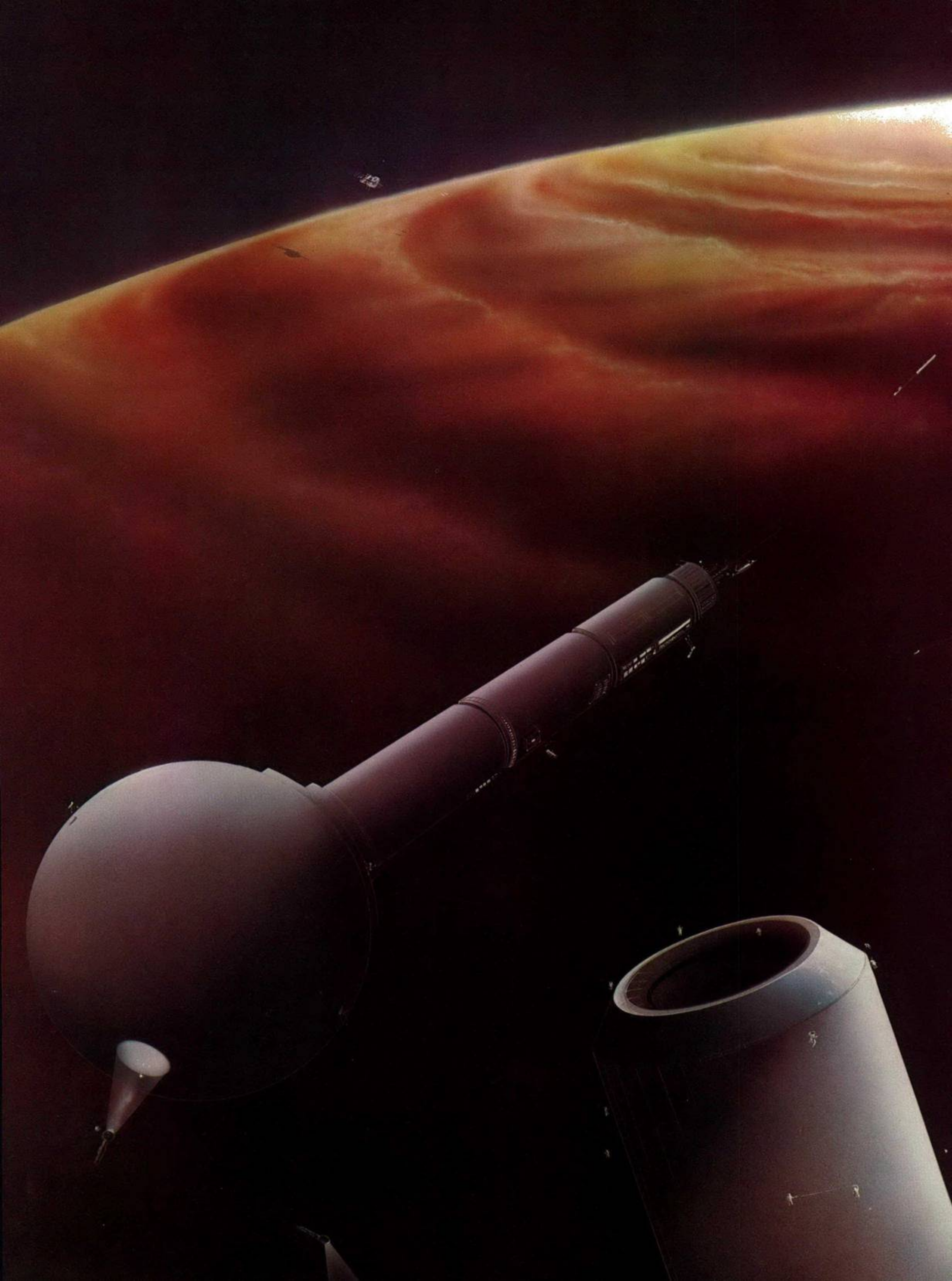
Meteorites, the terror of "B" science fiction movies, in reality constitute an almost negligible hazard. A large slow moving asteroid-ark of this type could expect one major collision every few *million* years. The real danger, from Shepherd's point of view, is the escape of the ark's interior atmosphere through tiny cracks in the hull. One hundred milligrams per second (about a gallon per minute) of air, seeping from a million ton vessel over a 500 year period, amounts to a loss of 1,500 tons of gas — hardly an unimportant situation for the crew!

So manned starflight is possible, though only on terms that few of us would care to accept — namely, a one-way trip. The hazards of being cooped up in a hull (even a very large hull) for several hundred years are poorly understood. The social and psychological repercussions of being packed like sardines for such a long period of time will be difficult to overcome. For most individuals, such a voyage could spell madness or even murder, and Bernal clearly recognized this. It seems that sending even highly motivated, socially stable people would be difficult without using powerful emotional controls, drugs, or highly controlled upbringing and education on them.

As if that weren't enough, the gene pool of hereditary characteristics among the crew, even on a large vessel, would be dangerously small. A simple solution would be to carry along a frozen sperm bank or some comparable medical technology to inhibit genetic drift.

Taking all these factors into account, Dr. Robert D. Enzmann of the Raytheon Corporation submitted a workable multigeneration starship design to the New York Academy of Sciences in 1964. The Enzmann starship has since come to be known as the "flying iceberg".

Basically, the starship is a cylinder 300 feet in diameter and 1,000 feet in length. On the front end of this cylinder sits a 1,000 foot diameter "snowball", made up of frozen deuterium (heavy hydrogen). This ball of 12 million tons of deuterium serves as fuel for eight Orion-type nuclear-pulse units at the aft end of the starship. The snowball gives the added benefit of radiation protection to the main body of the vessel. A central load-bearing core, 50 feet in diameter, runs the entire length of the cylinder in order to deliver the deuterium to the engines. Actually, the cylindrical portion of the starship consists of three identical 300 foot long modules docked end to end. All these drum-like modules could contain as many as 700 smaller submodules. The submodules surrounding the central core area would be used as living quarters, store rooms, and work and recreation areas. The outer layers of submodules are comprised primarily of bulk material to serve as radiation shielding for the inner decks. This bulk is made up of the modules' main nuclear reactor as well as various store rooms, heat exchang-



ers, airlocks, land craft storage, observation areas and communications equipment.

The Enzmann starship would begin its voyage with 200 individuals and have enough room for a maximum future ship population of 2,000. During the coasting part of the trip, the cylinder is spun around on its longitudinal axis to establish an artificial gravity. Upon reaching their destination, the travelers may (presumably) wish to come home eventually. The mother ship, too big and fragile to land, will remain in orbit while the smaller, sturdy landing craft replenish the snowball for the return trip — assuming there are planets on which the necessary materials can be found.

But one solitary flying iceberg will not make the journey alone. Enzmann suggested that a fleet of 3 to 10 such ships would be a definite advantage on a long mission. The modules are designed to weather any catastrophe; even if one module is completely destroyed, the two remaining sections can be disassembled and transfered to another ship. This idea blends strength and flexibility, allowing the greatest number of people to survive.

The nuclear-pulse engines used in the Enzmann starship differ from that suggested by Dyson. Dyson's design called for one nuclear bomb to be detonated a half mile behind the vehicle. The flying iceberg has eight units, each containing the entire explosive energy of a nuclear blast inside a gargantuan chamber, and venting that force aftward. As unbelievable as this sounds, engineers say it is quite possible. With this far more efficient system, Enzmann believes his ship could reach a peak velocity of 30 percent of the speed of light.

This is one of the few points with which some of Enzmann's colleagues disagree: In order to reach the speeds mentioned by Enzmann, the ship would need to "stage". As the design now stands, the flying iceberg is capable of about 10 percent of the velocity of light — which actually isn't bad when you consider that our present space probes can only attain speeds of *1/20,000* the speed of light!

At such speeds, a flying iceberg could reach Alpha Centauri in a little over 50 years. Most of the original crew would still be alive to see their destination — making it a far more satisfying journey.

A recent British Interplanetary Society study, dubbed Project Daedalus, proposed a new high speed version of the nuclear-pulse jet. The study describes a 68,620 ton unmanned probe that could deliver a 500 ton computerized payload to Barnard's star to carry out a series of sounding missions. Within the engine, micropellets of a deuterium and helium-3 (two protons and one neutron) mixture are fired into a magnetic field an astounding 250 times per second, where they are simultaneously heated and compressed by four high powered electron beams. A 400 foot cup-shaped shell made of molybdenum would absorb the energy, pushing the craft forward. Two such engines designed to boost the probe for a period of five years (2-1/2 years apiece) could achieve a final velocity of about 14 percent of the speed of light.

Assembling an Enzmann type starship in orbit about Jupiter, crews work around the clock to ready the mating collars between the craft and its engineering module (foreground) which will drive the ship. Work crews swarm over the engineering module making final checks, while in the background others inspect the fuel sphere and living modules of the spacecraft. Once assembled, checked, fueled, and thoroughly tested, the starship will depart on a generation long trip to a nearby star. Artwork by Mark Paternostro.

To save fuel, the star probe would be on a flyby trajectory. After spending 47 years crossing the 36 trillion miles to Barnard's star, the spacecraft would release 10 to 20 smaller probes as it streaks through its target star system in less than 10 hours. Six years later, the signals would be monitored by scientists back on Earth.

Such exploration by proxy can only be carried out by a reasonably wealthy, stable and scientifically advanced interplanetary culture. A society of this type would be able to economically absorb the costs of a large interstellar fleet. Jupiter would make an excellent assembly area for extrasolar expeditions. Very large structures could easily be built in the absence of gravity near Jupiter, but the main reason is that Jupiter is a potential source of hydrogen fuel! Recent measurements of the Jovian atmosphere have shown that it contains about 20 percent helium. Although only a tiny portion of that is helium-3, there are sufficient amounts of it to fuel 10 trillion Daedalus type starprobes!

All these sober studies show that even at the present time, there exist ways of reaching for the stars. The fact that they might not work well is not critical — they would work.

Jules Verne — considered a very daring thinker for his time — once attempted to predict what airborne transportation would be like around 1950. The best he could come up with was huge elegantly decorated balloons, beneath which comfortable gondolas would swing. These balloons could travel from coast to coast in a matter of weeks. The point is that in Verne's time, the balloon was the ultimate means to allow man to fly. Now, of course, we take our heavier-than-air flying machines for granted.

Today's technology has provided us with *our* ultimate means to fly to the stars. While these designs may never be implemented, we are left with the prospect that sometime in the next few centuries, the price will be right to allow human communities to raft out into the abyss.

What the force of events impelling us to make such a voyage will be — or even whether it will be made — cannot be foreseen, but the option exists.

Thomas R. Schroeder is a freelance artist and writer who has been interested in astronomy and spaceflight for as long as he can remember. He received his B.F.A. from the Minneapolis College of Art and Design in 1975.

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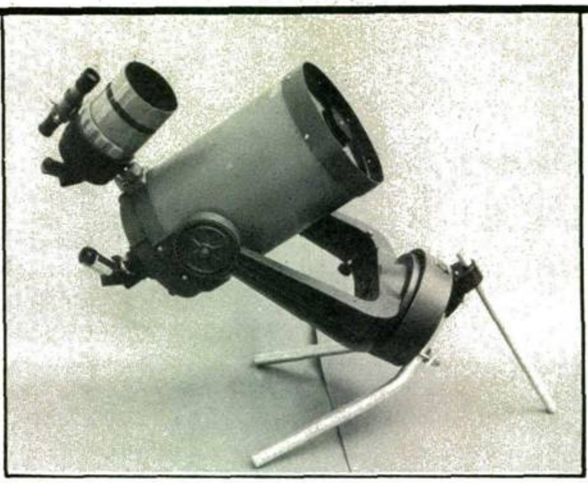

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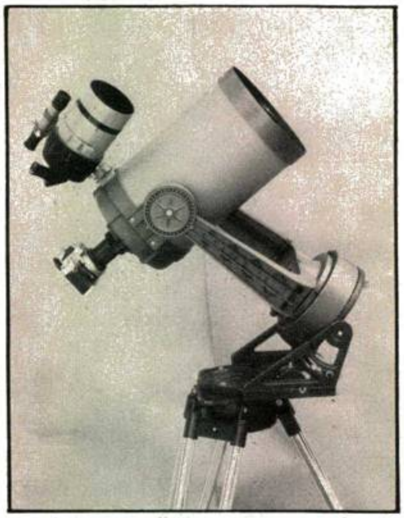

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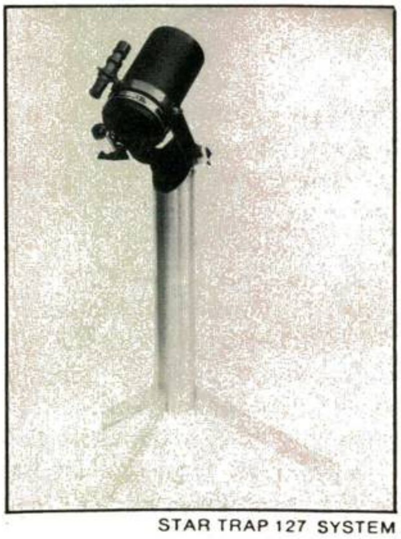

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PROBING THE NEAREST STAR

by
James E. Oberg

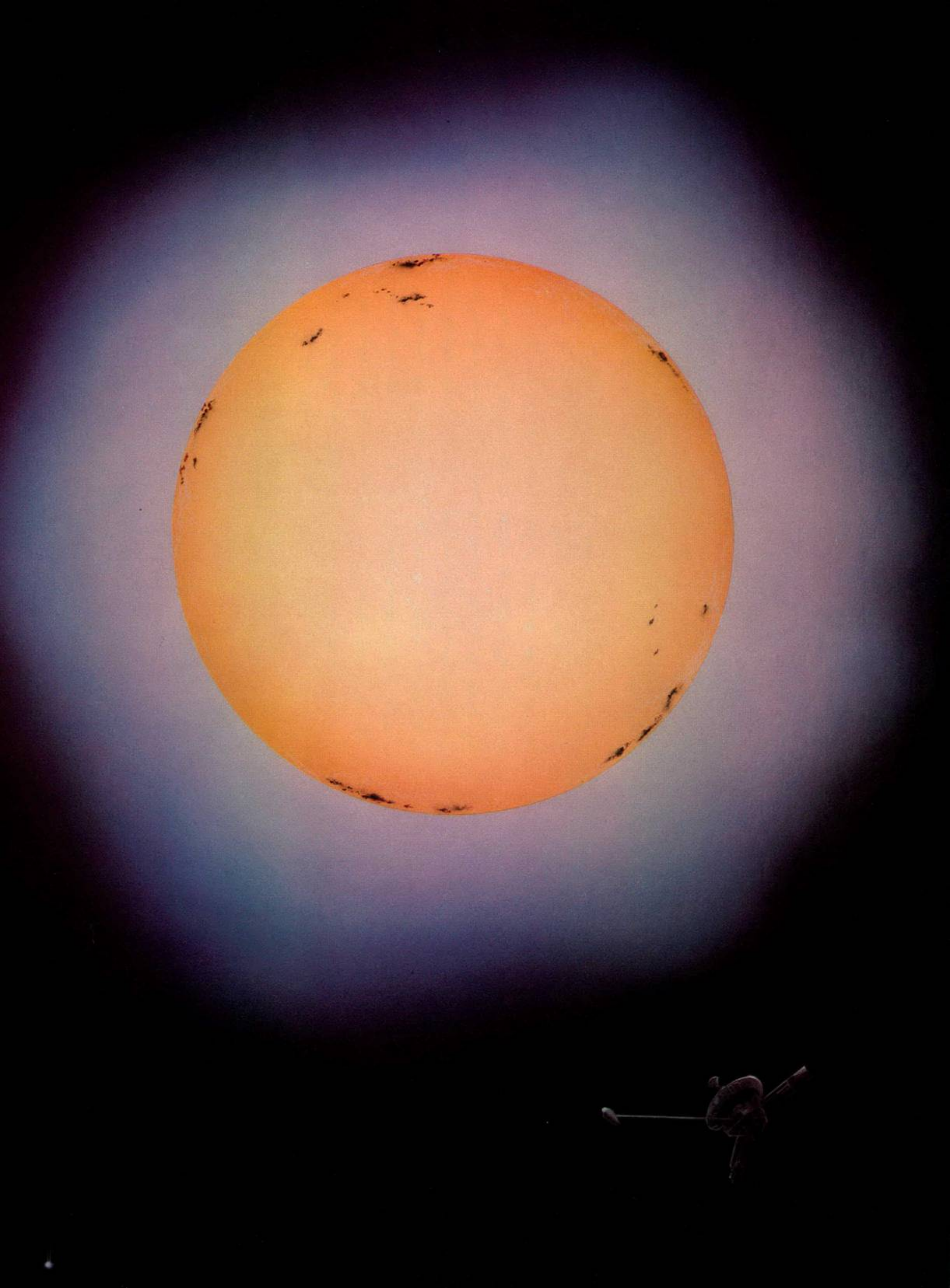
The United States launched the world's first solar probe 17 years ago. This probe sent back data on the solar wind and magnetic fields far beyond the influence of Earth's own. Contact was lost at a range of 20 million miles.

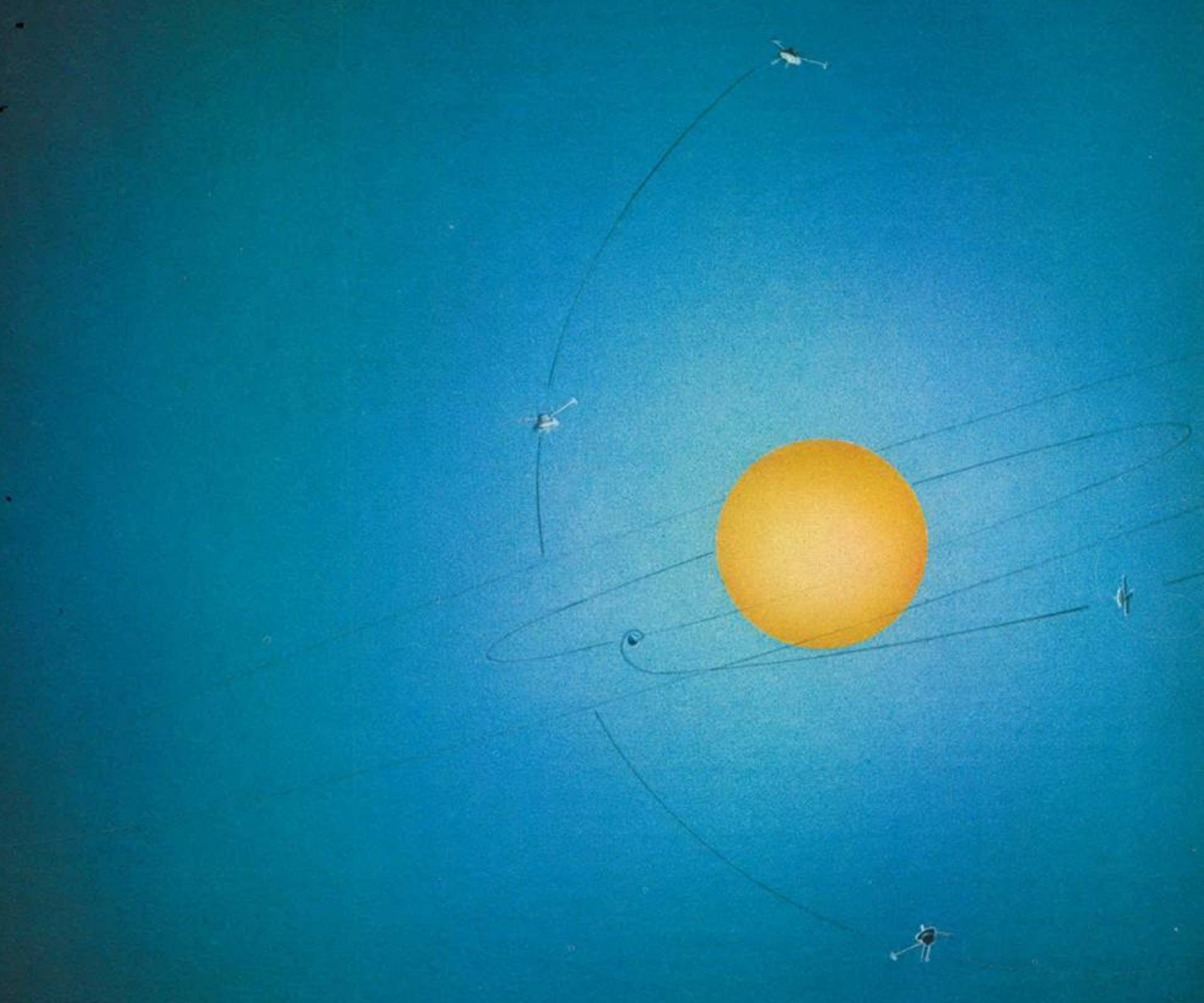
Later interplanetary probes and Earth satellites carried solar monitoring instruments, but they were on short or low trajectories, and did not contribute to the day-to-day solar monitoring which solar physicists needed. In the mid-1960s, however, four small Pioneer probes (numbers 6, 7, 8 and 9) were put into solar orbit, pacing Earth, with two pulling ahead and two pulling behind. Along with two Helios probes launched a few years ago, these spacecraft now form a sun weather network with active stations strung all the way around Earth's orbital path. (Some of the probes on the opposite side of the sun from Earth are 200 million miles away.)

The Pioneer Jupiter probes (numbers 10 and 11) are still watching the sun — years after their primary missions at Jupiter have ended. Both are traversing new regions of the solar system and new sections of the sun's field of influence. Pioneer 10 is heading away from the sun, having crossed the orbit of Saturn on its way out of the solar system. Pioneer 11, meanwhile, is swinging back across the solar system on course for Saturn. Along the way it is temporarily rising above the ecliptic plane, in which all planets — and all previous spacecraft — have been restricted.

The view of Pioneer 11 on its "out of the ecliptic" (OOE) path has been revolutionary. The probe is not rising far above the ecliptic (only above solar regions of about 10 degrees north latitude), but returned data has led to new thoughts about the structure of the sun's magnetic field. The data has also whetted the appetites of solar physicists for probes that will rise much higher out of the ecliptic, ultimately passing directly over the poles of the sun. Scientists want to put a spacecraft into *solar*

One astronomical unit from the sun, almost directly above the pole of the sun, a solar probe makes vital new measurements of a region of space previously unexplored. The solar wind, the magnetic fields between the planets, and solar system debris would become better understood from such missions. Furthermore, our solar system's interaction with the rest of the galaxy — effects hidden in the ecliptic plane — would be measured directly for the first time. Artwork by Mark Paternostro.

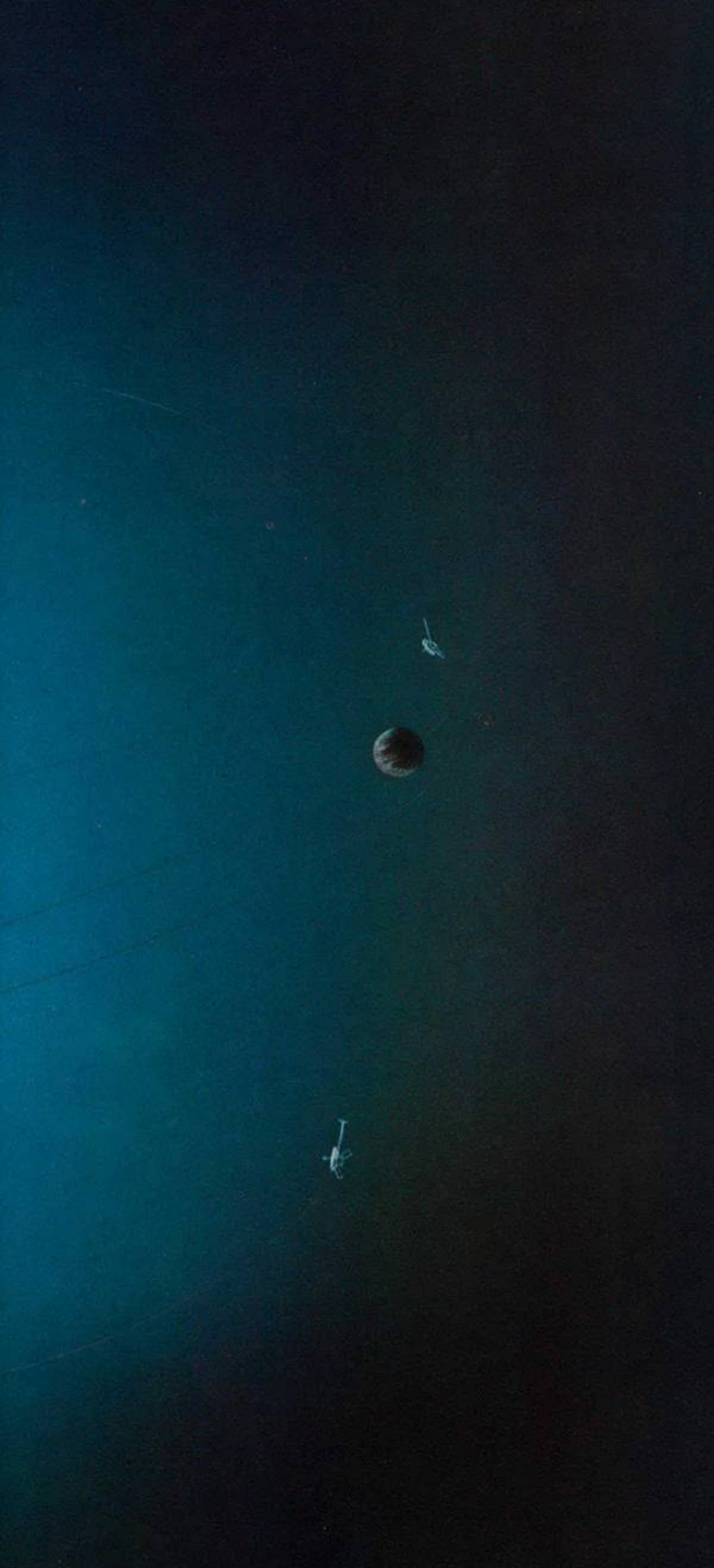




polar orbit. It would explore the last major region of the solar system which has not been previously studied, and would extend our understanding of the sun's forces from two into three dimensions.

How can a probe be put into a solar polar orbit? The problem is one of launch dynamics. All space probes on interplanetary trajectories begin their flight with Earth's forward momentum. After the seven-mile-per-second escape velocity has been achieved (mainly to get away from Earth), the probe travels at 18 miles per second (30km per second — Earth's orbital speed) along with Earth in its motion around the sun.

The easiest way to reach the polar regions of our sun is by way of Jupiter. The change in orbital speed required to rise out of the ecliptic plane is too great to be made directly from Earth, so the probe will be sent out to Jupiter where it will be aimed in close to that giant planet. Swinging around Jupiter, it will rise out of the ecliptic plane, and then return to the sun from high above the ecliptic to accomplish its scientific mission. Artwork by Mark Paternostro.



If additional rocket power is used to increase this speed by 10 percent or so, the probe will coast out from the sun and reach the orbit of Mars (if it is launched at the appropriate date, Mars will be there waiting for it). On the other hand, decreasing this forward speed by about 10 percent will allow the probe to drop inward toward Venus.

To escape entirely from the solar system, a probe would need an increase of about 40 percent over Earth's orbital speed. But to fall straight into the sun, a probe would need to kill off the entire 100 percent of Earth's forward speed. This last figure should dispel the old space myth about objects falling into the sun; dynamically, at least, it is easier to fall into any other local star!

Even worse, to send a probe into a right angle turn in order to put it into solar polar orbit would require an additional impulse of 140 percent of Earth's forward speed. Combined with the seven miles per second required to escape from Earth (a speed which is entirely eaten up by Earth's gravity — the probe "escapes" with zero velocity), this means that a solar polar orbiter launched by brute force rocketry would need three times as much booster speed as a simple interplanetary probe! Such rocket power is simply not going to become available in the foreseeable future.

Some other means of getting into solar polar orbit must therefore be found. We need some technique to turn the corner in orbital flight: to propel a probe up out of the ecliptic plane and into the as-yet-unexplored third dimension of the solar system.

The most interesting proposal so far calls for use of a large planet's gravity field to bend the probe's flight path. Gravity assisted missions have already been launched to Mercury (via Venus) and to Saturn (via Jupiter). But none of the inner planets are massive enough, and all the outer planets are in the wrong direction for a solar probe. Even so, one idea calls for use of Jupiter's gravity as the only feasible technique to reach the charted regions of the sun's territory.

Is it reasonable to fly past Jupiter — five times farther out from the sun than is Earth — in order to explore the sun? The giant planet may seem an unlikely detour, but it is, so far, the only possible road out of the ecliptic.

The OOE probe would be launched on an 18 to 24 month trajectory to Jupiter, and would be targeted ahead of and over either of the planet's poles. After a close flyby, the probe would be yanked straight up out of the ecliptic plane and flung back over the sun's polar regions several years later.

The first OOE solar mission will probably be a joint American-European project negotiated between NASA and the European Space Agency (ESA). While the planning for such a mission has been advancing, the launch date has been slipping from 1982 into 1983. There are other acceptable launch windows in 1984 and 1985, but thereafter the sun-Earth-Jupiter geometry will be unfavorable for economic launches for several years.

According to preliminary proposals, ESA would build two 600 pound spacecraft. The U.S. would provide two 500 watt radio-isotope thermal generaters (RTGs) for electrical power, and would also track the two spacecraft from the Deep Space Network's three giant space antennas in California, Spain and Australia. NASA would launch the payloads, using a Space Shuttle with additional upper stages.

After the long coast to Jupiter, the two probes would pass over the planet's poles — one over the north pole and the other over the south pole. Another two years of travel would see the probes directly above the polar regions of the sun at a range of about 100 million miles. They would continue to circle the sun in their five year orbits in opposite directions, with the plane of their orbits inclined at right angles to the ecliptic.

Scientific benefits could be immense. The solar wind, interplanetary magnetic fields, and density of gas and dust are certainly quite different in this region of space from the ecliptic-plane areas. As a bonus, scientists would like to be able to observe traces of the galactic fields — which in solar equatorial (near the ecliptic) regions are swept out by the solar fields. Unmodulated cosmic rays may be observed. Infall of galactic dust may be measured. The reduced sky background above the zodiacal light might offer the possibility of viewing very faint objects in the universe such as the extended wings of galaxies — objects that are usually lost in the background glare of ecliptic contamination. The plasma frequency may be greatly reduced, thereby allowing radio astronomical observations of the universe at much lower frequencies than is possible in the ecliptic plane. The OOE probe could give a polar overhead view of solar features such as streamers and large polar coronal holes. Quite simply, it would see the sun as it has never been seen before.

The instrumentation of such probes would be similar to that of Helios sun scouts now in solar orbit, as well as Pioneer probes now escaping from the solar system. Coronagraphs and magnetometers would be important, as would cosmic ray experiments at various energies. Plasma experiments, electron detectors, zodiacal light sensors, and micrometeoroid dust analysers are also likely candidates for the first OOE flights. NASA and ESA are currently accepting proposals for experiments; at a later date, members of the Science Working Team will be chosen from those who have submitted proposals.

Considering the long flight times of the Jupiter detour, and the rapid advance of space engineering, it is conceivable that the Jupiter swingby method may become obsolete before it can be launched. Two new propulsion techniques may indeed make the brute force route possible: They are *Solar Electric Propulsion* (SEP) and the *solar sail.* Both promise very low, long acting thrust. The OOE mission, without a real need for precise interplanetary navigation, may be an ideal candidate for the first space tests of these radical new propulsion systems.

The SEP uses solar power in the form of electricity generated by solar panels to propel fuel at a small but steady rate. It is the latest version of *ion thrust*, first popularized decades ago. Already, NASA engineering tests in the Space Electric Rocket Test program have used Earth satellites equipped with small ion engines that have fired for months at a stretch. The SEP for an OOE mission would need to fire for more than a year or two.

Solar sails exploit the pressure of light and the solar wind to create thrust on their thin, wide surfaces. A sail more than 1,000 feet square would be needed for an OOE mission, and it would also take several years for the probe to make its way into a purely polar orbit over the sun. Along the way, however, it would step-by-step be probing regions never before explored.

Any probe designed to monitor features on and just above the sun's chromosphere should ideally keep these features in constant view. One approach is the probe to be in a *heliosynchronous* orbit which keeps it above the same point on the sun's surface, restricted in this particular case to the sun's equatorial plane (which is not precisely the same as the ecliptic, but quite close!). Circling the sun every 25 days or so at a range of 15 million miles, the probe would face temperatures never before imagined for any manmade object. The problems of survival and operation in these conditions will be a challenge to the space engineers of the 1990s.

Challenging, too, is the *solar plunger* probe (perhaps appropriately named Icarus), which someday will be dispatched to within one million miles of the sun's surface. It will face radiation 100,000 times more intense than that near Earth. The sun's tremendous gravity will accelerate the probe to more than 500,000 m.p.h. at perihelion, where the flaming sun will fill half of the sky for the new Icarus. Problems of communications with Earth will also be severe; perhaps a modulated laser beam will replace our radio telemetry systems.

Icarus could be programmed to fire a powerful rocket engine just before perihelion, altering the probe's path and propelling it upward from the ecliptic plane on a solar escape trajectory. As it heads out into interstellar space directly above the sun's pole, the probe would relay new unique data on solar galactic interaction.

The potentials of out-of-ecliptic and near-sun exploration have barely been scratched because of the tremendous velocities required. For space exploration buffs who have kept scorecards of planets which probes have visited, there need be no disappointment as the latest missions cover almost all of the remaining planets. There are new worlds to conquer, and new uncharted regions which are today only blanks and question marks on the maps of space scientists. Space is three dimensional; the entire ecliptic plane, with its planets and asteroids, occupies only two of them. Up to now, the third dimension has been the exclusive domain of comets, unimaginable solar forces — and perhaps more. Soon we, too, will be there.

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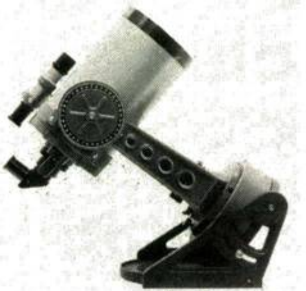

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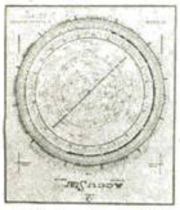

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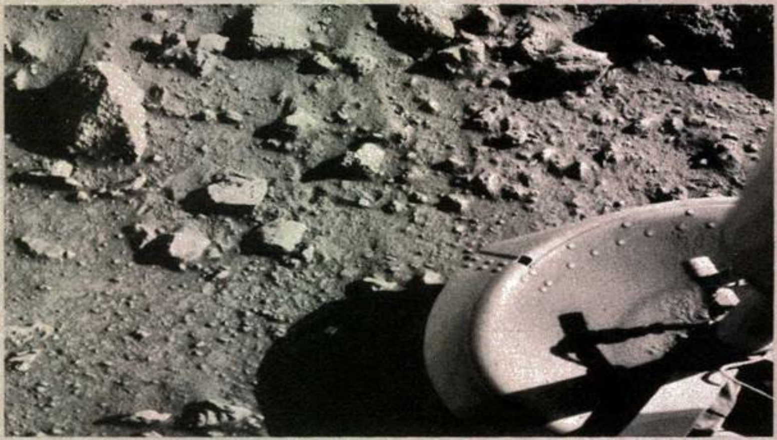
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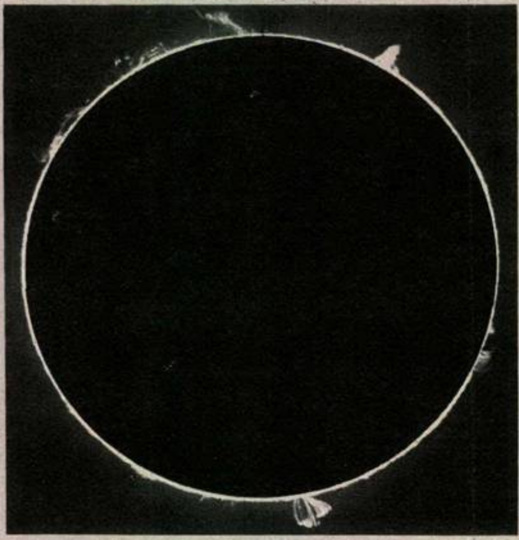
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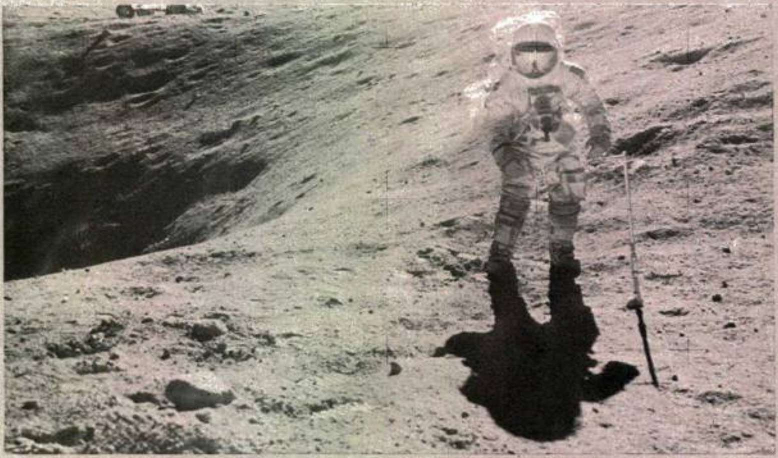
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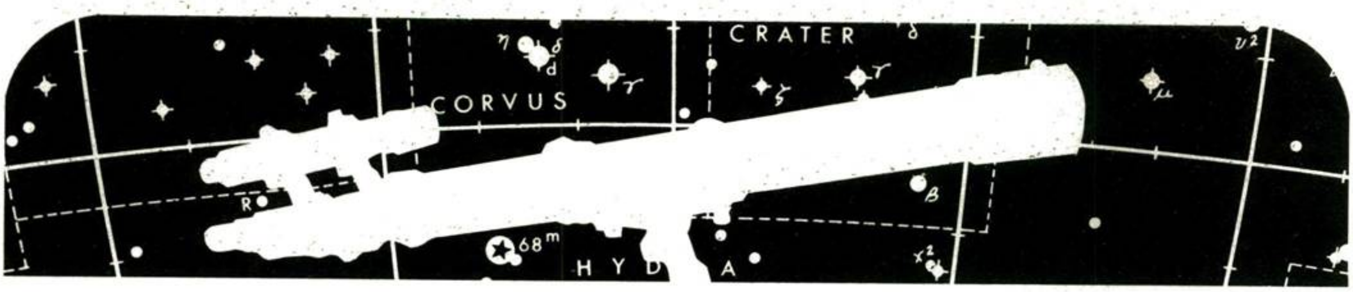


Building A 6" Reflector
Part 3: Assembling Your Telescope

by
Alan P. Witzgall

In the early part of this century, if you wanted a telescope, you had to make it from scratch. You were stuck with the rather tedious and demanding job of optical designing and fabrication, with exact machining of parts for both telescope and mounting, and did all of it usually without outside help. Still, as most telescope makers today agree, the excitement of finally using a new, somewhat "custom" instrument on a double star and seeing it split cleanly into two tiny diamondlike points with black space between, makes up for all the difficulties involved!

Many optical companies have opened since World War II, helping to make the work in building your own telescope much simpler. Off-the-shelf parts are readily available — at reasonable cost — to anyone who wants a good telescope, and the finished telescope usually has a lower cost than those commercially assembled.

In this article, we'll outline the assembly of a Newtonian reflecting telescope. The instructions given here apply to all apertures commercially available, from a tiny 4-1/4 to a huge 16 incher. As our example, we will use a six inch Newtonian with 48 inches focal length (f/8, for the photography buff), because that's probably the most "all-around" telescope there is!

The Mirror's the Thing

The first item to be considered is the optics, including the secondary flat. The two mirrors — the primary and the secondary — work together to produce an image to the eyepiece or camera film. The better their surface accuracy (or wave-rating) the better the image. For example, 1/16 wave means that the surface of a mirror does not deviate from a mean surface more than 1/16 of a wavelength of green light. The smaller the fraction, the higher the quality of your optics.

Considering the work involved and your specific problems in arranging workspace at home, you may decide to make your primary mirror yourself or buy it — whatever is best for you. Good mirrors are available today from many suppliers.

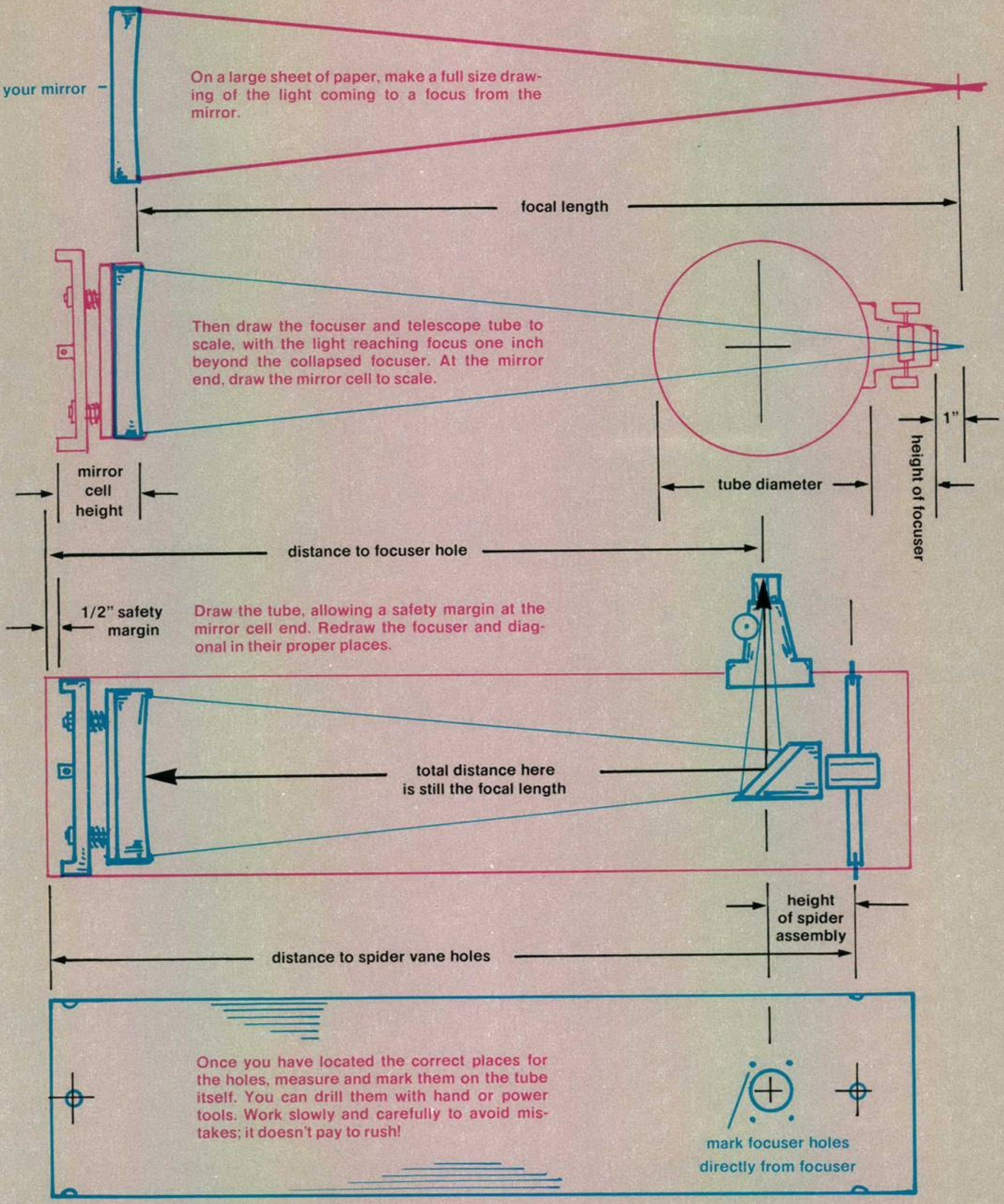
Once you have the primary — either your own or a commercially made mirror — your first thought

Hole Placement for a Newtonian Telescope

48.5	Measured focal length of telescope mirror
-3.5	1/2 diameter of the telescope tube
45.0	
-2.5	Height of focuser (fully "in" position)
42.5	
-1.0	Focusing allowance for visual observing (for photography, allow 2-1/4 inches)
41.5	Result: separation between front of primary mirror and diagonal
+2.0	Thickness of primary mirror cell
+0.5	Safety allowance (it is better to err wide)
44.0	Result: distance from back end of tube to center of the focuser hole
+3.5	Distance from middle of diagonal mirror to middle of spider vanes
47.5	Result: distance from back end of tube to spider holes

Layout for A 6" Reflector

Before drilling any holes in your telescope tube, you must carefully determine where they should be drilled.



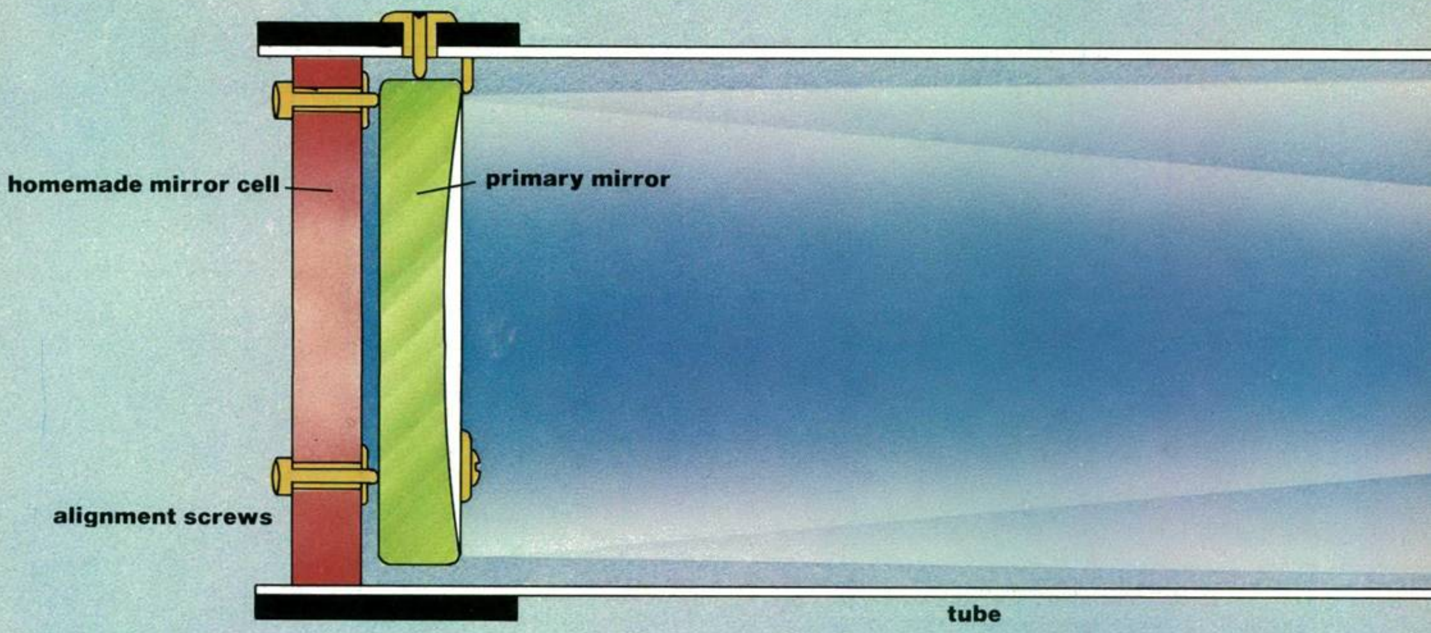
On a large sheet of paper, make a full size drawing of the light coming to a focus from the mirror.

Then draw the focuser and telescope tube to scale, with the light reaching focus one inch beyond the collapsed focuser. At the mirror end, draw the mirror cell to scale.

Draw the tube, allowing a safety margin at the mirror cell end. Redraw the focuser and diagonal in their proper places.

Once you have located the correct places for the holes, measure and mark them on the tube itself. You can drill them with hand or power tools. Work slowly and carefully to avoid mistakes; it doesn't pay to rush!

your mirror
focal length
1"
height of focuser
tube diameter
mirror cell height
distance to focuser hole
1/2" safety margin
total distance here is still the focal length
height of spider assembly
distance to spider vane holes
mark focuser holes directly from focuser


Your Homemade 6" Telescope

should be to find its *exact* focal length, to about ± 1/4 inch. This is most easily done by forming an image of the moon, or even a very distant streetlight (one at least 1,000 feet away) on a white card. Have a friend use a tape measure to find the exact distance between the card and the mirror — that's the focal length.

Secondary Mirror

As a general rule, the minor axis of the secondary should be 1/4 the aperture of the primary mirror; for a six inch, this means a minor axis of 1-1/2 inches. Most commercial telescope builders use a secondary of 1-1/4 inches for a six inch f/8, but this results in some loss of field — a problem called *vignetting*. You can eliminate this problem in the design stage. It's well worth the extra cost involved!

Mirror Cells

To hold the primary and secondary mirrors securely in alignment, you'll need *mirror cells*. Mirror cells not only hold the mirrors, but also permit you to move them into perfect alignment and then lock them into place.

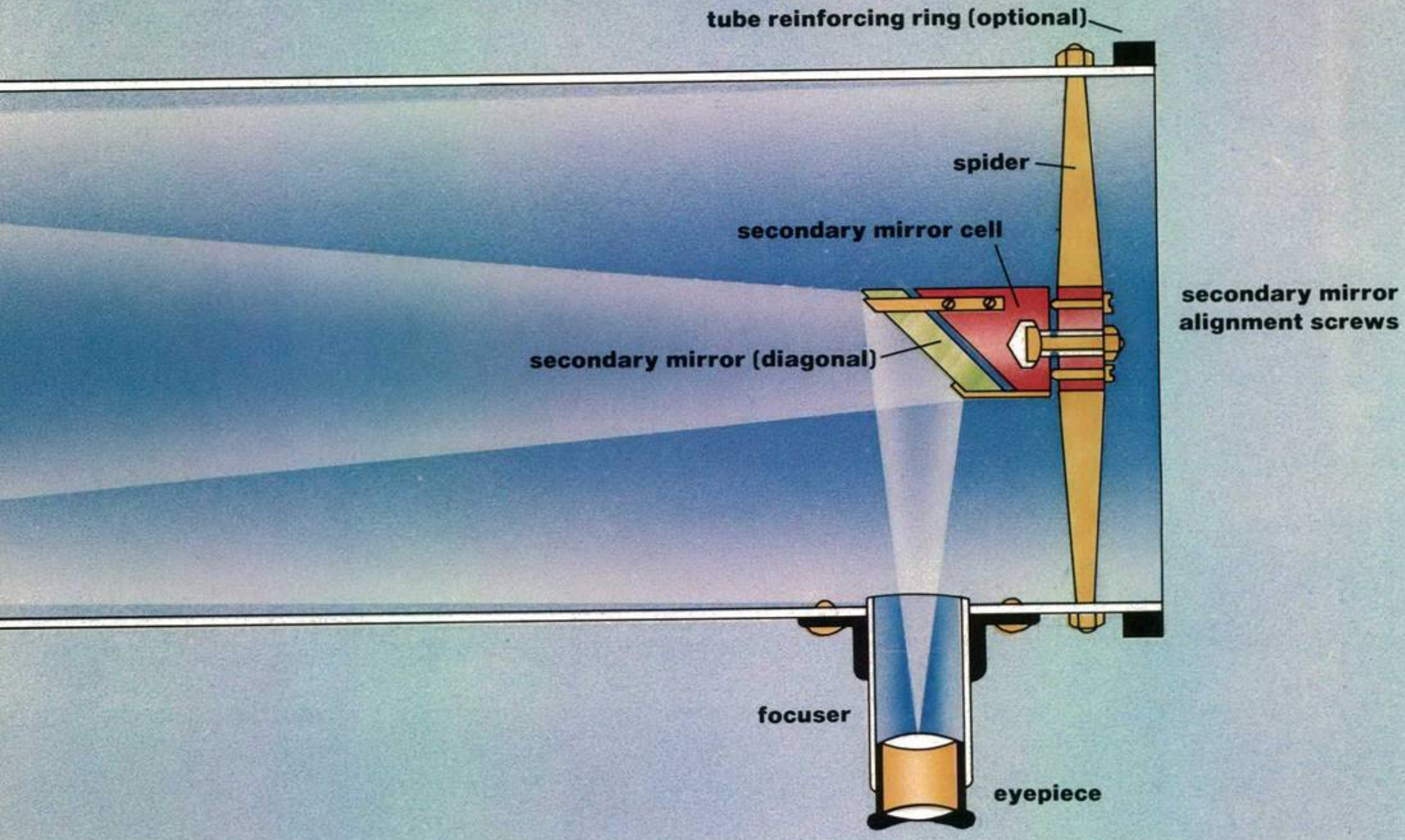
You can make the cell yourself from either wood or metal, or you can buy one of the many commercially available ones. The drawings on page 27 show how a mirror cell works; dimensions are not critical as long as it holds the mirror and fits inside the telescope tube! If you're handy with tools, it's worth the effort to make it yourself.

Support of the secondary's cell requires some care, because the secondary is in the middle of the tube and not very accessible. Of all designs available to hold the secondary, the best is the old classic — the *four vane spider*. It holds the secondary rigidly in place and creates only a minimum of scattered light, or *diffraction*, in the eyepiece. In an eyepiece, a star will appear as a point of light, with a faint cross superimposed over it. *Single vane supports* are less expensive, but their performance is marred by their inability to be adjusted easily and their extreme sensitivity to vibration. *Three vane supports* create six spikes of light around stars — dimmer than the four spikes produced by a four vane spider, but nevertheless more of them!

Focusers

To hold the eyepiece, a rack and pinion focuser is better than the simple slide in-and-out drawtube. Those with *helical racks* are the best, as they minimize tooth-stripping backlash, while allowing for greater control on delicate focusing. For the photographer, some rack and pinion focusers are equipped with locks to insure constant focus on the film throughout a long exposure.

Many astrophotographers prefer an "oversized" or two inch diameter eyepiece mount, because they assure full illumination of the field right to the


tube reinforcing ring (optional)
spider
secondary mirror cell
secondary mirror alignment screws
secondary mirror (diagonal)
focuser
eyepiece

Whether you use parts you've built yourself or commercially available components, a cutaway view of a six inch reflector will look a lot like this. Light from the sky enters from the right and strikes the mirror; for purposes of clarity, light from just one star is shown bouncing back to the secondary (also called the diagonal) and into the eyepiece. Diagram by M.R. Boelke.

edges. Most standard 1-1/4 inch focusers cause some loss of light at the edge of the field. In any case, you can change your mind later and replace a 1-1/4 inch focuser with a two inch.

Telescope Tubes

Having discussed the mirror supports, eyepiece focuser and finder, we have one more item to consider — the one that holds it all together: the telescope tube. The tube can be of laminated cardboard, phenolic, wood, fiberglass or aluminum. Cardboard is not very good for larger aperture instruments (over eight inches), unless you stiffen it with a fiberglass overcoat. Phenolic plastic tubes are excellent from the standpoint of stiffness, and will also act as a good insulator from the heat of your hand on the tube. They can be brittle, however, if not treated carefully. Fiberglass tubes are perhaps the best for telescopes: They are good insulators, are not readily susceptible to flexture, are lightweight, and can be easily machined.

If you are a woodworker, you might enjoy building your own tube. It can be square or hexagonal, plain or fancy, mahogany or plywood. Wood is a good insulator, relatively inexpensive, and easy to work with. Round tubes are convenient — but almost impossible to make from wood. Aluminum, because it conducts heat too well, is suitable only for larger apertures where strength is necessary.

Lay Out Your Telescope

On a large sheet of paper, make a full scale drawing of your telescope (you'll find it'll save you trouble later). Begin with the mirror (measure its thickness) and draw lines to indicate the path light takes as it comes to focus. From the point of focus, extend two lines 1/2 inch to either side: This corresponds to the size of the field in a one inch eyepiece. (Use the illustrations on page 27 as an example in making your own drawing.)

Now we'll begin to allow for spacing the optics inside the telescope. From the point of focus, measure back toward the mirror 1/2 the inside diameter of the tube. For a seven inch diameter tube, it would be 3-1/2 inches. Add the height of the focuser turned all the way down (usually about 2-1/2 inches), and then — if you want to try photography — measure off another 2-1/4 inches. Otherwise, you should allow one inch for ordinary visual observing only. (For a six inch reflector, we've done an example for you, as you can see in the box on page 26.) Add to this the

	6" mirror (aluminized, overcoated)	Diagonal mirror	Mirror Cell (cast aluminum)	4 Vane Spider	Tube	Focuser	Finderscope	Additional comments
Cal-Astro Optical Laboratories, Inc. 615 S. Tremont St.-Dept.AM Oceanside, CA 92054 (714-722-3009)		1.3"-$32.00 1.5"-$35.00 uncoated						sell many types of flat mirrors
Cave Optical Co. 4137 E. Anaheim St.-Dept.AM Long Beach, CA 90804 (213-434-2613)	$79.00	1.3"-$6.50 1.55"-$12.00 aluminized	$15.00	$12.00	$48.00 (fiberglass)	1.25"-$22.00 2"-$35.00	8x50mm-$39.50	telescope without mount - $200.00
Criterion Mfg. Co. 620 Oakwood Ave.-Dept.AM West Hartford, CT 06110 (203-247-1696)	**Information not available at presstime**							
E & W Optical, Inc. 2420 E. Hennepin Ave.-Dept. AM Minneapolis, MN 55413 (612-331-1187)		1.25"-$8.50 1.5"-$12.00		$18.00	$13.50 (7"x5' aluminum)	1.25"-$15.00		also sell aluminizing services and grinding supplies
Edmund Scientific Co. Edscorp Building - 101 E. Gloucester Pike-Dept. AM Barrington, NJ 08007 (609-547-3488)	$89.50	1.25"-$9.00 1.5"-$11.95	$12.50	$7.50	$12.50 (paper 60") $33.50 (aluminum 60")	1.25"-$16.95 2"-$39.50	7x30-$27.00 6x50-$51.95 (see catalog)	complete telescope with mounting-$285.
A. Jaegers 691 Merrick Road-Dept. AM Lynbrook, NY 11563 (516-599-3167)	$49.50	1.25"-$7.00 1.5"-$8.50	$9.25	$1.50 (stalk support only)	$20.00+ (7"x48" aluminum)	1.25"-$11.00 2.594"-$37.50	7x-$21.50 ring mounts-$5.25	many useful optical items
Meade Instruments 721 W. 16th - Dept. AM Costa Mesa, CA 92627 (714-646-9281)	$49.95	1.3"-$8.00 1.52"-$11.50	$14.00	$14.95	$29.00 (7-3/8"x50" phenolic prepainted)	$14.95 (1.25") to $29.95 (2")	6x30mm with mounts-$14.75 7x50mm-$29.95	
Kenneth Novak & Co. Box 69 - Dept. AM Ladysmith, WI 54848 (715-532-5102)			$11.95	$5.98 (mirror holder) $8.50 (spider)		1.25"-$14.95 2"-$29.95		other telescope parts available also
Optica b/c 4100 MacArthur Blvd. - Dept. AM Oakland, CA 94619 (415-530-1234)	$118.00 (6" f/7)	1.3"-$8.40 1.52"-$12.07	$19.95 (fiberglass) $13.50 (cast aluminum)	$10.00 (mirror holder) $8.14 (spider)	aluminum, fiber board, fiberglass sold by the foot	1.25"-$45.12 2"-$53.17 (other models available)	6x30mm-$34.46 12x40mm - $61.62	also sell equipment and films for astrophotography; offers aluminizing
Pacific Instruments P.O. Box 1876-Dept.AM Pocoima, CA 91331 (213-896-3016)	**Information not available at presstime**							
Star Instruments P.O. Box 1606 - Dept. AM Costa Mesa, CA 92626 (714-540-8729)	$44.95	1.52"-$11.50	$14.00	$12.95	$29.95 (7"x50" phenolic)	1.25"standard-$14.95 2"deluxe-$29.95	6x30mm-$14.95 8x50mm-$29.95	
Star-Liner Co. 1106 S. Columbus Blvd. - Dept. AM Tucson, AZ 85711 (602-795-3361)			$15.95					mainly large complete telescopes
Telescopics 6565 Romaine St.-Dept.AM Los Angeles, CA 90038 (213-469-6321)	$65.50	1.3"-$9.00 1.55"-$11.50	$14.50	$19.50		1.25"-$31.50 2"-$48.00		
Unitron Scientific 101 Crossways Park W.-Dept. AM Woodbury, NY 11797 (516-364-8046)							10x42mm - $49.00 12x62mm - $125.00	mainly refractors
University Optics 2122 E. Delhi Rd.-Dept.AM Ann Arbor, MI 48106 (313-761-0430)	$65.95	1.3"-$8.95 1.5"-$15.00	$12.50	$14.95	$23.95 (7"x50" phenolic)	1.25"-$14.95 2"-$31.50 (4 models)	8x50mm with rings-$39.00 (many models)	all parts for a 6" telescope kit - $164.00
Willman-Bell, Inc. Box 3125 - Dept. AM Richmond, VA 23235 (804-320-7016)		1.3"-$9.00 1.5"-$12.50						mirror testing equipment; mirror grinding supplies

Note: This list is intended as a guide only, and is not warranted to be a complete listing of suppliers. For complete specifications on components, contact the company and request their current catalog and price sheet. Prices listed here may not be current, and all prices are subject to change without notice.

thickness of your primary mirror cell (usually 2 to 2-1/2 inches). This final figure is the distance from the end of the tube to the point where the hole must be cut for the eyepiece focuser. If you use a drill with a hole saw, you can cut a nice neat hole in the side of any of the types of tubes we've discussed. The hole should be 1-3/8 inches or 1-1/2 inches in diameter. Drill four small holes for the screws that hold the focuser, using the focuser itself as your guide.

On the diagonal support, measure the distance between the center of the diagonal mirror in its cell and the center line of the spider vanes. Add this distance to the focuser distance as well. With a tape measure, mark off four equally spaced points at this distance for the four vane spider bolts. About 1/6 of the circumference of the tube away from the eyepiece holder, drill the holes for the brackets of the finder telescope. Here, be certain that the holes line up square to the optical axis (the long dimension of the tube).

After drilling all the holes you'll need, but before installing any hardware in the tube, you'll want to paint the tube. Paint the inside with flat black enamel. This is a tricky, time consuming job if you use a brush. But if you seal all the holes with masking tape, including the ends, and then pour a pint of paint into the tube and roll it, turn it and spin it in every possible way, the paint will cover everything inside very quickly. Then pour the excess paint out and set it on end to drain completely. This job is *very* messy. Paint the outside any color that looks good. Light colors are best because you can see the tube in the dark and not bump into it.

First, install the focuser on its large hole. Next, put the secondary mirror into the spider; then install the spider, taking care to center the support bolt in the tube before tightening the nuts in place. It may take some extra adjusting, but it's important to get it "dead center". Install the primary mirror in its cell, taking care not to get fingerprints on the surface of the mirror, and then bolt the primary mirror cell in place. Finally, attach the finder brackets and install the finder in the brackets.

Alignment

After all the optical components are installed, it's necessary to align: a) the secondary mirror at a 45 degree angle to the primary; b) the primary with the center of the tube, and c) the finder to the main instrument.

First, align the secondary. An empty film canister with its bottom cut off (use a sharp knife) is a necessary tool. Perforate the lid with a large sharp needle as close to the center as possible. (This centering is important!) Put it into the eyepiece holder, and rack the holder as far as it will go. Now look through the small hole. When you view this way, any misalignment or decentering of the mirror end in the diagonal will be easy to see. Using the adjustment bolts, rotate the secondary on its axis (by its support bolt), and then center the reflection of the primary end of the tube in the middle of the diagonal mirror.

Telescope Mirrors: Buy or Do-It-Yourself?

You may be faced with a difficult question if you want to make a telescope: Should you make the mirror yourself? In previous issues of ASTRONOMY (April and May 1977), you've seen how it's done: grinding the glass, polishing, then interpreting the shadows of the Foucault test. But it didn't look easy, and besides, you live in a 17th floor apartment. What should you do?

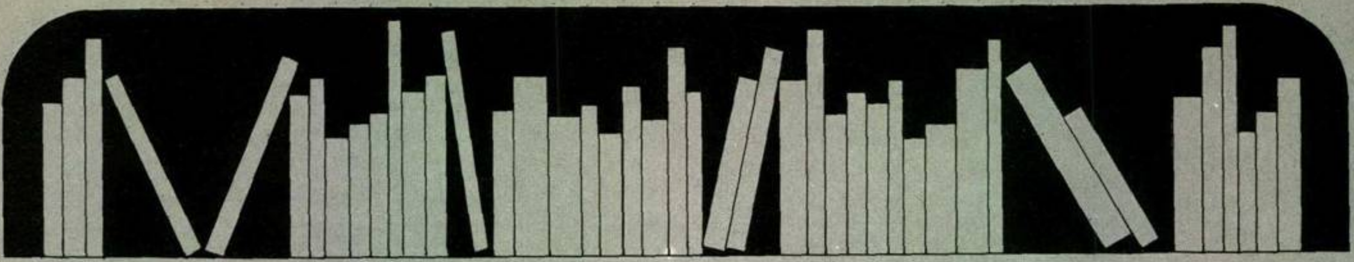
It really depends on you! A six inch mirror kit costs $15 to $25, and you'll pay another $10 or so to have it aluminized — plus, lots of your own time. A finished mirror may cost $50 to $100, depending on where you buy it. So you don't save a lot by doing it yourself, but you will learn how to make a mirror! If you want to have a bigger telescope someday (maybe a 12-1/2 incher), the price difference will be much greater. If you gain experience with your first six inch, you'll find a 12-1/2 inch pretty easy. But if you try to learn on a 12-1/2 inch, you'll have a lot of learning to do!

So, grinding a mirror is a learning experience — and it's hard to go wrong with a six inch. Plus, you'll get the thrill of being involved in astronomy right up to your elbows. And if you're short on time and don't have a place to work? Then buy a mirror, put it in your telescope, and be sure to use it!

When you have centered the diagonal mirror as well as you can, carefully tighten all adjustment bolts. Next align the primary. By using the three adjusting bolts on the primary cell, center the image of the spider in the reflection from the main mirror. Again take your time; when you're satisfied with the centering of the images, tighten any locking bolts on the cell. (See "Tune Up Your Telescope", ASTRONOMY, December 1975 for more information.)

Finally, align the finder. By sighting along one side of the tube, center a distant streetlight (or any distant object) in the eyepiece. Using the adjusting screws on the finder brackets, center your target in the finder field as well. Then point the telescope to any bright star in the sky (here's the big moment, gang!), center it in the finder and focus on it in the main scope. You should be able to focus on the star without trouble . . . if everything was done right!

EDITOR'S NOTE: You may have noticed something: We haven't mentioned the telescope's mounting yet! Next month, we'll discuss mountings you can buy or build for your telescope, what to look for in a mounting you buy, and what to do if you want to build it yourself.



ASTRONOMY REVIEWS

Missiles and Rockets
by KENNETH GATLAND

256 pages, hardcover, $6.95
Macmillan (1975)

This "pocket encyclopedia of spaceflight in color" is a fine little book of specifications, descriptions, and performance histories of missiles and rockets built throughout the world over the past few decades. The precise target audience, however, is a little obscure: Is the book for reference, for casual reading, or for some combination of the two?

A stunning visual overview of space hardware is presented through 100 pages of color photographs and sketches. Even the most widely read space enthusiast will find new revelations here. If any collection of rocketry photographs can be complete, this one must be.

Credit for the quality of the collection must go to Gatland, a respected British spaceflight specialist, and editor of "Spaceflight".

The test reveals his deep familiarity with the topic and the ease with which he handles difficult engineering topics. The esoteric art of building rocket engines powerful enough for moon flights is not as complicated as the media often implies. Gatland begins with the first real space rocket (the V-2) and closes with the Space Shuttle Main Engine. In between, we read about the Thor, the Atlas, and the Saturn — famous names on the road into space which once filled the newspapers but now have found their permanent home in history books.

Military missiles are also described in amazing detail. The American solid fuel Minuteman and Polaris rocket weapons may be familiar to most readers, but how many people know the significance of the Soviet SS-17 or the French SSBS-S-3? Beyond the technology, Gatland gives readers enough information to realize what Strategic Arms Limitation Talks are all about.

Illustrations and text on Soviet space launchers are excellent, especially considering the veil of secrecy and distortion which must be penetrated by an analyst. The "proton launcher" has never been seen by Western specialists; Gatland gives some exclusive drawings based on dogged and inspired research. An even bigger semimythical "Soviet Saturn-V" superbooster has never even been acknowledged by Moscow, but Gatland reports that it has blown up at least three times in a row in the past seven years.

British and Chinese rocketry programs are also described in detail. A European satellite launcher called "Arianne" is being designed to be competitive with the Space Shuttle, while Chinese astronauts are probably now in training. These are space headlines of tomorrow but will not be a surprise to readers of this perceptive book.

The only rockets not mentioned are revolutionary new designs being studied by commercial space transportation corporations in Europe and America — but these plans are kept secret and are very nebulous in any case.

You can depend on this book both for reference and entertainment. *James E. Oberg.*

Skylab Science Experiments
edited by GEORGE MORGENTHALER

257 pages, hardcover, $20.00
American Astronautical Society (1975)

Preliminary scientific results of the Skylab space station (1973-74) are now beginning to appear in print. Once the flights ended and the headlines "died", space scientists began work in earnest on reducing the immense piles of magnetic tapes, films, logbooks and specimens gathered by nine astronauts during 271 days of space activity.

The experiments fell into four broad categories: physical science (including deep space, solar astronomy, Earth atmosphere); space based applications (such as crystal growth, alloy solidification, and operational problems); life sciences (cellular growth, vestibular side effects, and implications for new manned space flights), and Earth applications (land use studies, water resource management, and agricultural, forest and range inventories). The transcript of a panel discussion about "where do we go from here?" follows the main articles.

Although space enthusiasts may be fascinated by all of these sections, the first one is of most interest to astronomers. The table of contents lists titles of papers by scientist-astronauts Parker, Schweickart and Garriott.

But for some odd reason, these three papers are included in abstract form only, adding up to a grand total of four pages with half of them blank! This is therefore not a good book in which to seek information on Skylab astronomy.

The other sections are fairly good, provided that readers are interested in the subjects covered. Detailed results of the Skylab "space factory" experiments are presented, with excellent illustrations and occasionally puzzling results. In space medicine, the results of human cell studies (no change whatsoever in space), space sickness (its choice of victims is still mysterious), and general medical effects of weightlessness (noticeable but quickly reversible, and no barrier to very long space missions) are all presented. Computer-tabulated study photographs of Earth resources are included, providing evidence of why forest rangers are spaceflight fans.

This is, of course, not a complete report on all Skylab experiments; many of those performed on the last crew visit are not even mentioned. No astronomy is included. But, this is a good beginning for a decade of scientific discoveries based on Skylab. *James E. Oberg.*

Pulsating Stars
edited by B. V. KUKARKIN
translated by R. HARDIN

320 pages, hardcover, $37.50
Halsted Press (1975)

The various families of pulsating variable stars represent one of the most important and often confusing areas of astronomy. While ASTRONOMY readers might find a clear, introductory survey of the subject very useful, it is not likely that this book will prove very satisfactory.

Pulsating Stars is the first book of a five volume series on "Nonstationary Stars And Methods for Studying Them" to be translated into English from the original Russian edition (only four of the five volumes are currently scheduled for English translation). The series is intended for professional astronomers and graduate students with a substantial background in observational and theoretical astrophysics. As a result, a considerable amount of undefined jargon and mathematical symbolism are used throughout this book.

In addition, the format of the presentation lacks continuity. The book is divided into 10 chapters, each written by a Soviet expert on some aspect of pulsating stars. While use of multiple authors is common in books for advanced students and professionals who are familiar with the field, this approach is not well-suited for other readers because the writing styles and levels of presentation will necessarily differ from chapter to chapter.

Another difficulty with this book is the translation from Russian to English. Translations inevitably result in some phraseology which is at least amusing and, at its worst, downright confusing. For example, one is able to guess what is meant in chapter seven when the "kinematics" (meaning state of motion) of a dwarf Cepheid are termed "quiet". But readers who are not comfortable with more advanced astronomical literature may well be confused by expressions such as "values of system B" where "B magnitude" is meant, or "age" instead of "phase" of an observation. In the final chapter, one finds a very curious (and unsupported) statement that must be due to an error in translation: "Semiregular and irregular variables are probably the objects which aid us most in understanding the structure and evolution of stellar material."

Even the readers for whom the book is intended will be confused at times by the graphic material presented without clear labeling or textual explanation.

On the other hand, **Pulsating Stars** offers many very good things to the advanced reader. The first chapter presents a review of the theory of stellar pulsation, and is probably the most difficult section of the book. The remaining nine chapters primarily describe the observed properties of various pulsating star families — including classical, dwarf and population II Cepheids, RR Lyrae, RV Tauri, Delta Scuti, Beta Cephei stars, long period, semiregular, and irregular variables. Care is also taken to discuss the important and often difficult problem of defining membership criteria for these families.

This is an important compendium of properties of these stars, as well as a guide to literature on pulsating stars up to about 1968 when the manuscripts were completed (the original Russian edition appeared in 1970).

While advanced readers may well find this book useful as a reference, most readers of ASTRONOMY will probably find better ways to spend the $37.50 necessary to buy it. *D. E. Mook.*

Space Geology: An Introduction

by ELBERT KING

349 pages, hardcover, $16.95
John Wiley and Sons (1976)

Man's first physical contact with worlds beyond came when "rocks fell from heaven". Once geologists got their hands on these meteorites, they had a foot in the door of astronomy. This book details the justifiable and productive involvement between geology and astronomy.

Elbert King worked for NASA during the Apollo project, and later transferred to a nearby university to continue his studies of lunar rocks. This text was written for his college students, but can be read by astronomy enthusiasts as well — especially if they have some background in geology.

Those areas for which actual rock specimens exist are more strongly stressed: The moon gets 90 pages, and meteorites and tektites get another 80 pages. Where geologic and physical studies can be made, detailed results are also presented (impact craters receive detailed coverage in 70 pages). Where remote geologic sensing has been possible, smaller sections are presented (30 pages are devoted to Mars, by virtue of the Mariner 9 results).

Asteroids and comets rate only 18 pages, and the rest of the solar system is discussed in another 15 pages. This coverage is justifiable from the author's viewpoint.

But perhaps the thrust of the book has been determined less by a balanced appraisal of the importance of various topics, than by practical considerations of those areas in which the author has been personally involved. This might explain why volcanism is generally glossed over as a planetary phenomenon, and why words like "volcano", "lava" and "basalt" do not even appear in the index. Although individual volcanos of the moon and Mars are described, this topic may not have been covered in the depth it deserves.

The material which is included is covered very well. The meteorite section presents chemical analyses, speculations, some fascinating asides and personal experiences. It gives an excellent, first-class perspective on these stones from the sky.

"Some meteorites should come to us as secondary ejecta from the moon," King points out. "Somewhere in the collections of meteorites there should be pieces of the moon . . . . No lunar fragment, as yet, has been identified from presently known meteorites." This passage illustrates another strength of the book — the enumeration of things not yet done, of puzzles not yet solved, and of data already on hand but not yet carefully analyzed for the secrets contained inside.

King's close association with the geological exploration of the moon is also evident in this section of the book. The organization, explanations and descriptions found here are among the best ever written. Major patterns and minor details are woven together to present the tapestry of the moon.

"Another new mineral that occurs in lunar samples was named armalconite," King says. "The name is derived from the names of the flight crew of Apollo 11, Neil Armstrong, Buzz Aldrin and Mike Collins. After the discovery of this mineral in lunar samples, it also was found in terrestrial rocks." A student of the history of science will be pleased to notice this analog to the discovery of helium: first on the sun, and only then on Earth.

Theories of lunar formation have been modified by Apollo results, but there is still no obvious front runner. King makes a perceptive appeal to the "big picture" in presenting a criterion for lunar theories: "The processes that formed the moon must not be terribly unlikely events because there are too many of them in the solar system." These same observations may someday be applied to entire solar systems.

The closing section on "comparative planetology" is more a challenge than an answer to questions. This short section presents "the kinds of problems that must be attacked" — bulk compositions of the planets, degrees of differentiation, internal states and tectonic styles.

A reader looking for solutions will be dissatisfied. But upon reflection, one is compelled to admit that the most interesting problems in science are those for which we do not have all the answers, but for which we do have plans and programs for seeking the answers. This is what makes this topic, and King's presentation, so fascinating. *James E. Oberg*

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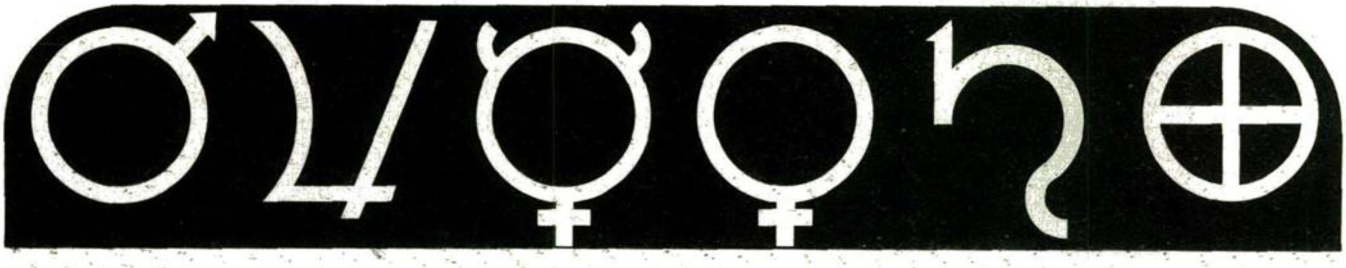


SKY ALMANAC

Perseids Pepper Planet

Most of the interesting sky events for August take place after midnight, so plan your observing schedule accordingly. Mars, Jupiter and Venus are all present in the morning sky. Be sure to watch these planets on the mornings of Aug. 9, 10 and 11; they will be equidistantly spaced in the sky, and the waning crescent moon will pass the same distance south of each in turn. Perseid meteors — currently the brightest and most reliable of meteor showers — are at their peak on Aug. 12, and you can watch them undistracted by moonlight. About the only thing happening during the evening this month is a fleeting apparition of Mercury.

Mercury

The planet nearest the sun is an elusive object at the best of times, and conditions for observing Mercury this month are not at their best.

Mercury is at greatest eastern elongation on the evening of Aug. 8, but the angle of the ecliptic over the western horizon is small, and Mercury will be only about 10 degrees above the horizon at sunset. If you have a clear view to the west, you might be able to get a glimpse of it (binoculars will certainly prove useful here). But if you really want to see Mercury, you're probably better off waiting until the much more favorable appearance it will make in the morning sky during the latter half of September.

If you live east of the Mississippi River, you may be able to witness an occultation of Mercury by the moon on Aug. 16. Only those along the Atlantic coast, however, will be able to see Mercury disappear behind the moon's dark limb after sundown. Between the Appalachians and the Mississippi, Mercury will reappear from behind the moon's lit crescent during twilight, while farther west the entire event takes place before sunset and cannot be seen. Again, a clear western horizon is a must for this event. Some optical aid (binoculars or a small telescope) will probably be necessary.

Venus

Venus is still very well placed for those who care to look at it in the predawn sky. It is by far the brightest object visible during the morning hours, despite the fact that it has faded considerably since greatest brilliancy in May — almost a full magnitude. Venus rises about three hours before the sun during the month. On the 11th, it will be a short distance (four degrees) north of the waning crescent moon.

Check Venus through your telescope on the morning of Aug. 20 when it passes only seven seconds of arc south of NGC-2392, the Eskimo nebula (one of the brightest planetary nebulae). The glare from Venus may reduce the nebula's visibility; ASTRONOMY would like to receive reports from observers on the aperture and/or power necessary to observe this appulse.

During September, Venus continues to rise about three hours before the sun. It will be in conjunction with Saturn on the morning of Sept. 18, and less than one degree north of the first magnitude star Regulus three days later.

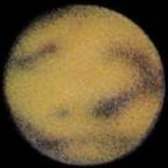
Mars

As the red planet gets nearer and nearer to Earth (approaching opposition next January), it is slowly brightening. During August, Mars' magnitude is +1.1 — just a bit fainter than the +0.87 magnitude of Aldebaran, the bright red star in Taurus. Mars will pass five degrees north of Aldebaran on Aug. 1.

Throughout the month, Mars is located in Taurus, moving into Gemini just before month's end. The moon

On the morning of May 14, 1977, the moon, Venus and Mars were very close to each other; the exact separation between the moon and the planets depended on observers' locations. These three photos were taken from the eastern United States. Top: The moon and Venus are seen through the trees in this shot from East Pittsburgh, Pa. Just visible through the branches is the red dot of Mars. This is a 10 second exposure on GAF 500 through a 135mm lens at f/2.8. Photograph by Fred Hafeli. Bottom left: The three bodies are seen here in an unobstructed view from Brooklyn, N.Y. A 300mm lens at f/4 was used for this two second exposure on GAF 500. Photograph by Bob Krutzel and Rudy Kokich. Bottom right: Closing in on the moon and Venus, this photo was taken near an exit ramp of a New Jersey expressway. This is a 1/125 second exposure on GAF 500, made with a Celestron 8 at f/10. Photograph by Michael R. Richardson.

Planet Finder



Ⓒ Ceres

Aug.	1	15
R.A.	13^h04^m	13^h21^m
Dec.	+0°35'	-1°58'
Mag.	+8.5	+8.6

Ⓐ Mercury

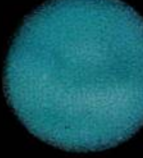
Aug.	1
R.A.	10^h30^m
Dec.	+8°54'
Mag.	+0.3

Ⓑ Mercury

Aug.	15
R.A.	11^h14^m
Dec.	+1°38'
Mag.	+0.8

Ⓜ Mars

Aug.	1	15
R.A.	4^h36^m	5^h15^m
Dec.	+21°35'	+22°48'
Mag.	+1.2	+1.1



Ⓝ Neptune

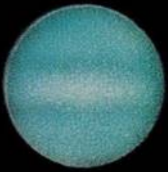
Aug.	15
R.A.	16^h48^m
Dec.	-20°55'
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

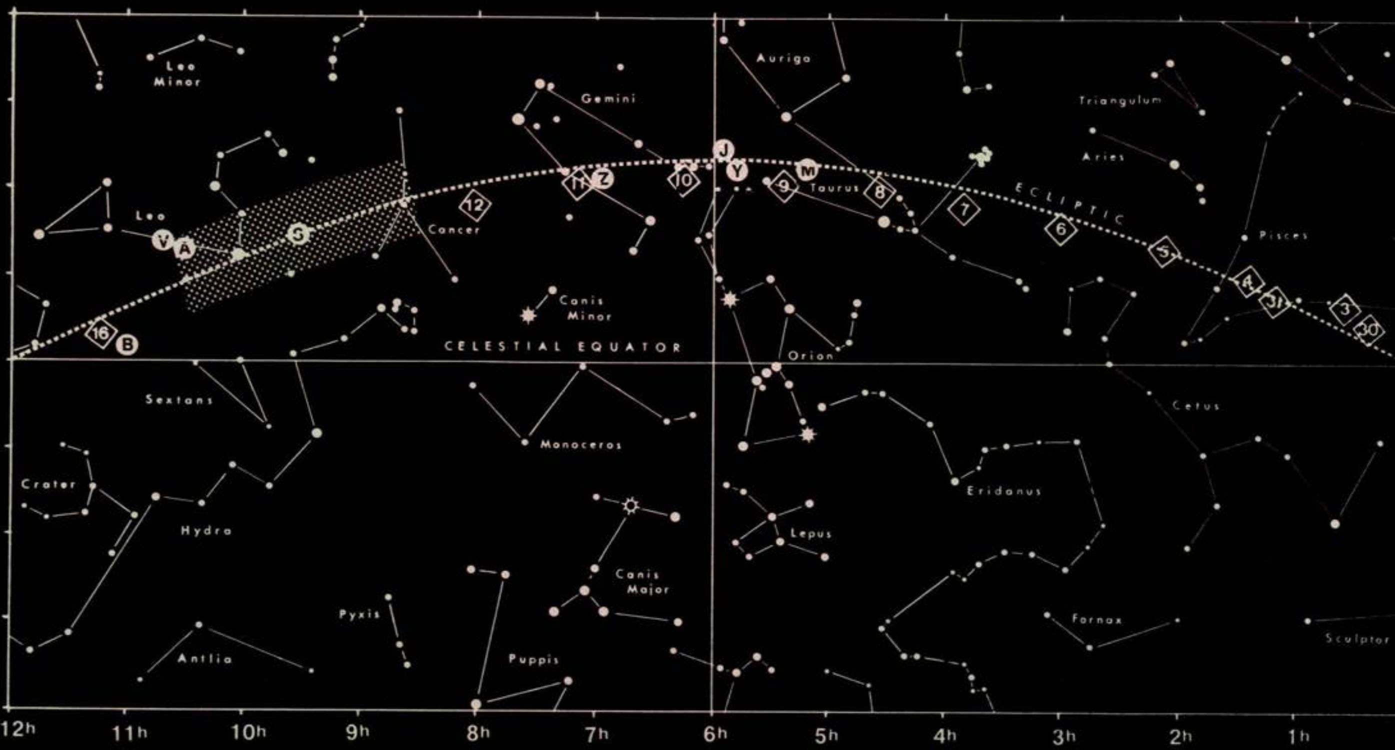
Ⓢ Saturn

Aug.	1	15
R.A.	9^h26^m	9^h33^m
Dec.	+16°05'	+15°32'
Mag.	+0.6	+0.7



Ⓤ Uranus

Aug.	15
R.A.	14^h23^m
Dec.	-13°48'
Mag.	+5.7

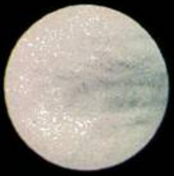

Leo Minor
Gemini
Auriga
Triangulum
Aries
Leo
Cancer
Taurus
ECLIPTIC
Pisces
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Monoceros
Cetus
Crater
Eridanus
Hydra
Lepus
Canis Major
Fornax
Sculptor
Pyxis
Antlia
Puppis
V
A
S
B
J
Y
M
Z
16
12
11
10
9
8
7
6
5
4
31
3
30
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

August 1977

Ⓥ Vesta

Aug.	1	15
R.A.	10h16m	10h42m
Dec.	+15°16'	+12°55'
Mag.	+8.7	+8.7



Ⓙ Jupiter

Aug.	1	15
R.A.	5h45m	5h56m
Dec.	+22°58'	+23°01'
Mag.	-1.6	-1.6

Ⓨ Venus

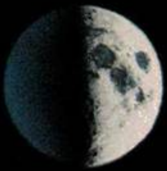
Aug.	1
R.A.	5h56m
Dec.	+21°36'
Mag.	-3.6

Ⓩ Venus

Aug.	15
R.A.	7h05m
Dec.	+21°30'
Mag.	-3.5

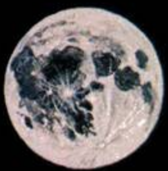
Ⓟ Pluto

Aug.	15
R.A.	13h09m
Dec.	+10°41'
Mag.	+14



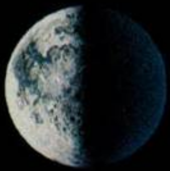
First Quarter

August 21



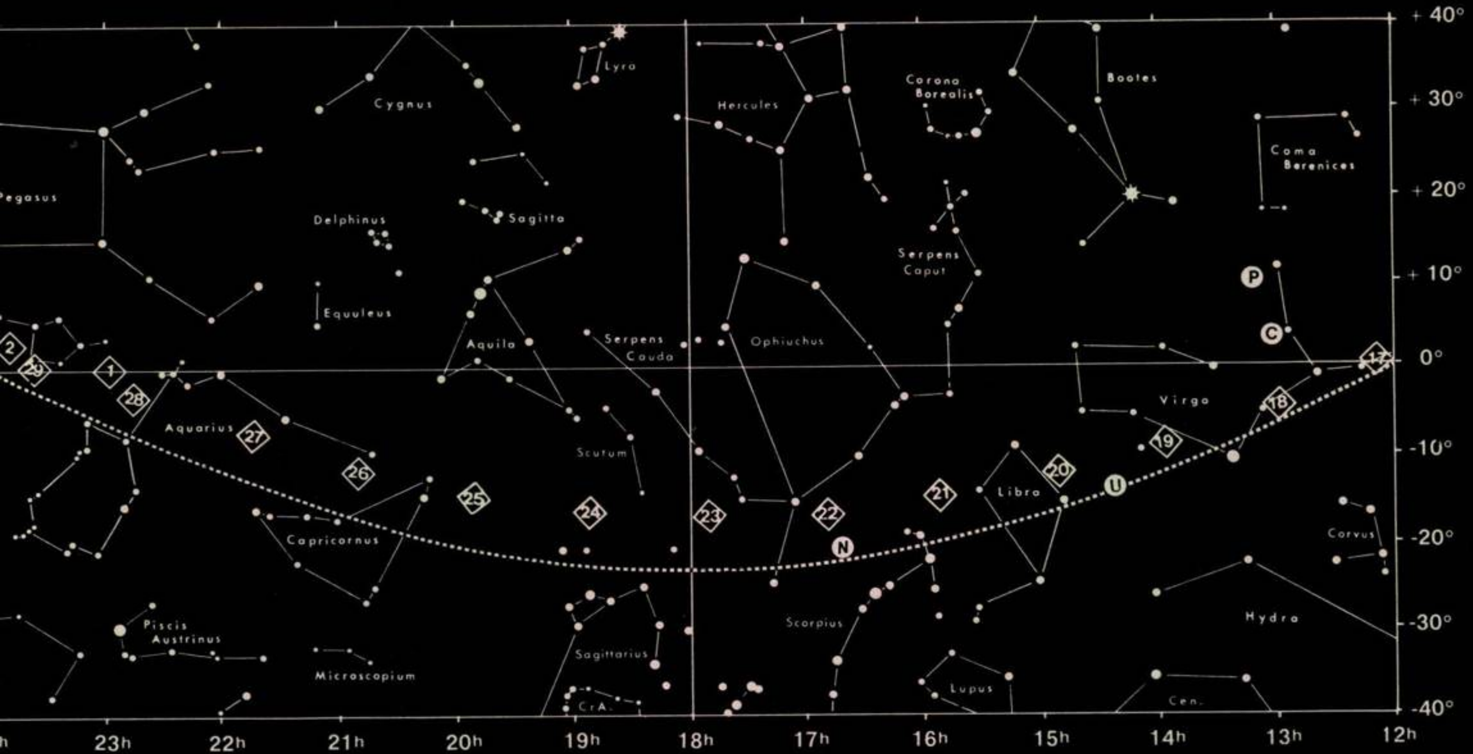
Full Moon

August 28



Last Quarter

August 6



+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Pegasus
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Corvus
Capricornus
Scorpius
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA.
Cen.
P
C
U
N
2
29
1
28
27
26
25
24
23
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23h
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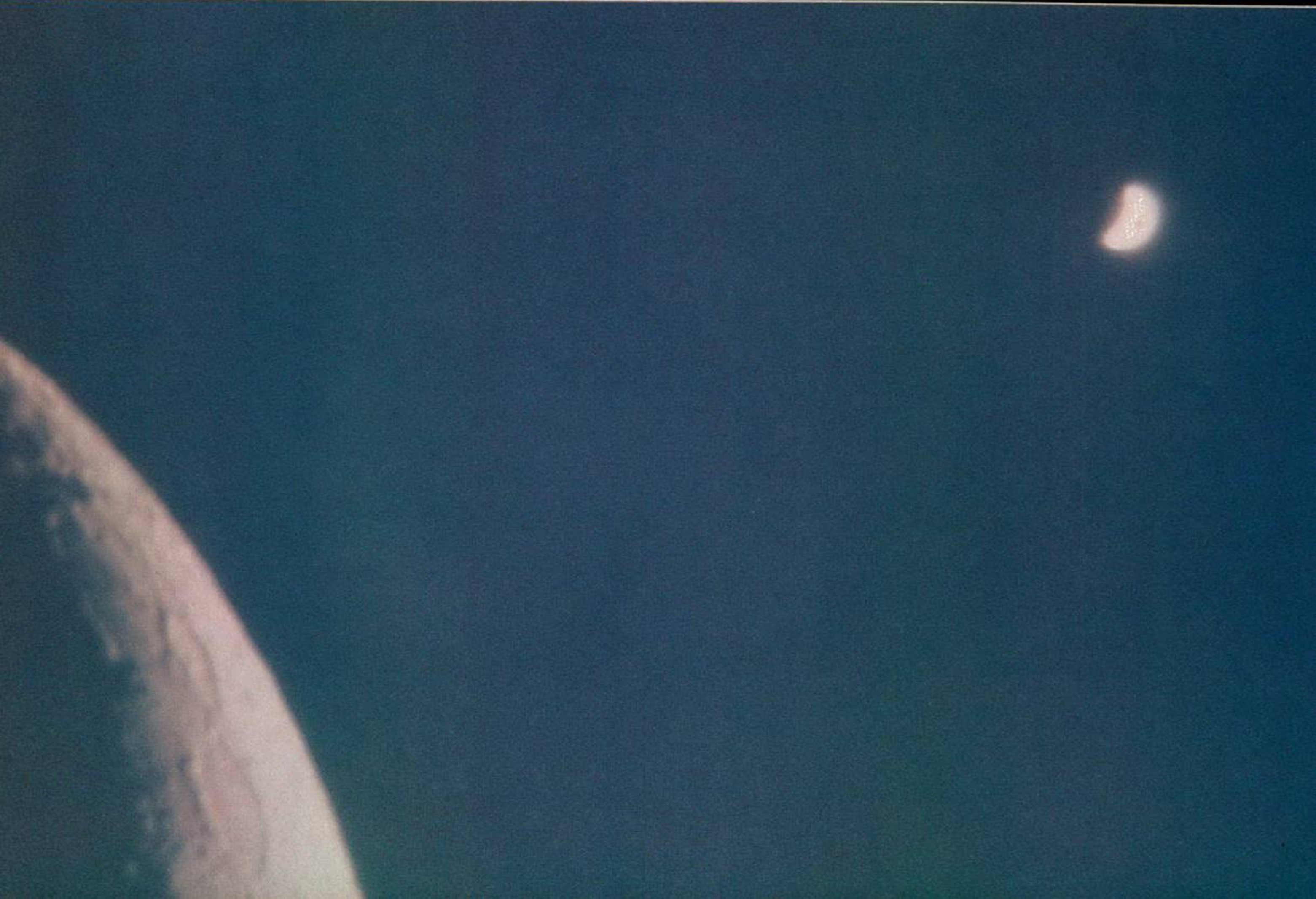
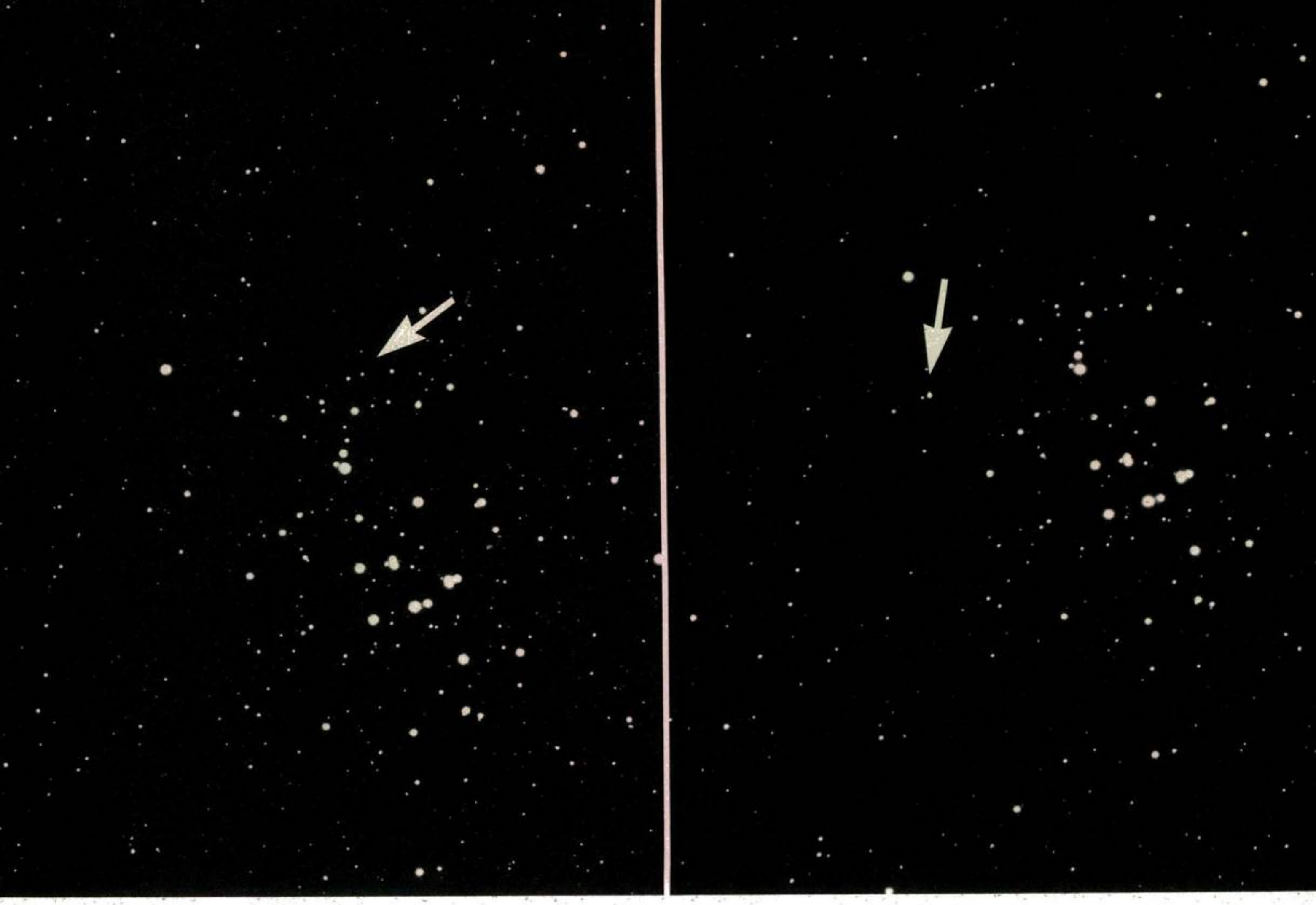
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.





Opposite page: More photos of the moon-Venus appulse are reproduced here. Top left: This is a 1/4 second exposure on Fuji 100, made through a 400mm lens from Green Bay, Wisc. Photograph by Ronald Parmentier. Top right: The moon and Venus are both reddened by horizon haze in this 1/4 second exposure on High Speed Ektachrome, obtained with the Dynamax 8 of the St. Charles Parish Planetarium in Luling, La. Photograph by James R. Westlake Jr. Bottom: Venus' crescent phase is easily visible near the tip of the moon's crescent in this photo made by the eyepiece projection method with a Dynamax 8. This is a two second exposure on High Speed Ektachrome. Photograph by Bob Krutzel and Rudy Kokich. Above: During March, asteroid 44 Nysa passed through M-44, the Beehive cluster in Cancer. These two photos show the asteroid's motion over a period of nine days. The picture at left is a seven minute exposure; that at right is a five minute. Both photos were made with a four inch f/5.6 astrograph at the Sonoma State College Observatory in Rohnert Park, Calif., on Tri-X film. Photographs by Paul L. Avellar.

passes five degrees south of Mars on the morning of the 9th.

Mars rises shortly before midnight during August and is high in the east by dawn. Its distinct red color makes it unmistakable. It will be especially beautiful when viewed against the deep blue morning twilight through binoculars.

Mars is slowly catching up on Jupiter, with which it will be in conjunction on Sept. 4. Watch the two planets slowly converging during August before next month's rendezvous.

Jupiter

Jupiter can be seen for about four hours before sunrise during most of August. Shining at magnitude -1.7, Jupiter is brighter than any other object in the predawn sky except Venus. As it heads toward opposition this December, Jupiter's distance from Earth decreases from 540,000,000 miles (865,000,000km) to 505,000,000 miles (810,000,000km). It moves from Taurus into Gemini during August, and on the 28th is just a degree south of the prominent open cluster M-35.

On Aug. 10, Jupiter is four degrees north of the crescent moon. It will be in conjunction with Mars on Sept. 4; the two planets will be separated by only 1/2 degree (about one moon diameter).

Saturn

Saturn is in conjunction with the sun on Aug. 13 and is too close to the sun to be visible throughout the month. It will reappear in the morning sky in September, and will be separated from Venus on Sept. 18 by less than 1/2 degree.

Perseid Meteors

Your best chance to see meteors this year will be for several days on both sides of Aug. 12, when the Perseid meteor shower reaches its peak. Because the moon is an extremely thin crescent rising very shortly before the sun at that time, its light will not interfere with observation of the shower (as it did last year). At the height of the shower, you can expect to see about 50 meteors per hour under clear, dark skies.

The Perseids receive their name from their *radiant* (the point in the sky from which they appear to be moving outward). The radiant is located in the constellation Perseus. Perseus is low in the northeast during the first half of August nights, rising higher in the sky as the night progresses until dawn, when it is halfway up in the northeast. To observe the shower, simply face Perseus and stay alert. The best time for viewing is after midnight, primarily because Perseus is higher in the sky, but also because after midnight, the part of Earth on which you're standing is moving "into the teeth of the storm" — that is, in the direction facing the shower's motion through space.

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Jim Schultz Lyons, Colorado

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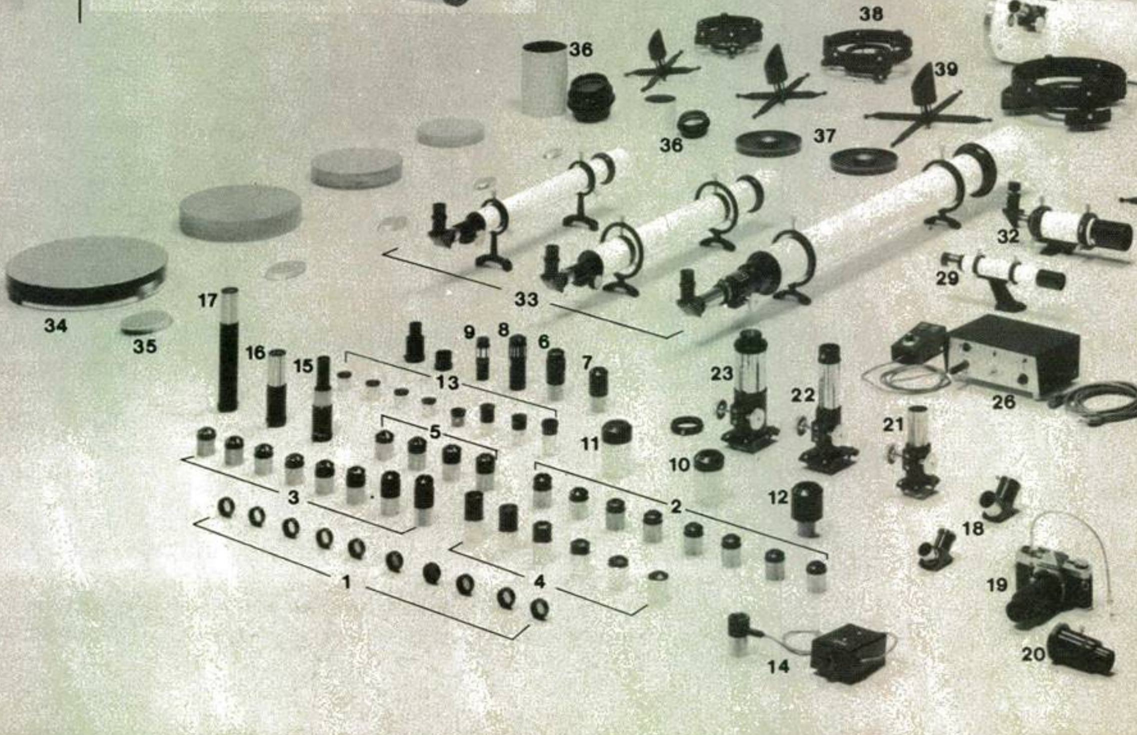

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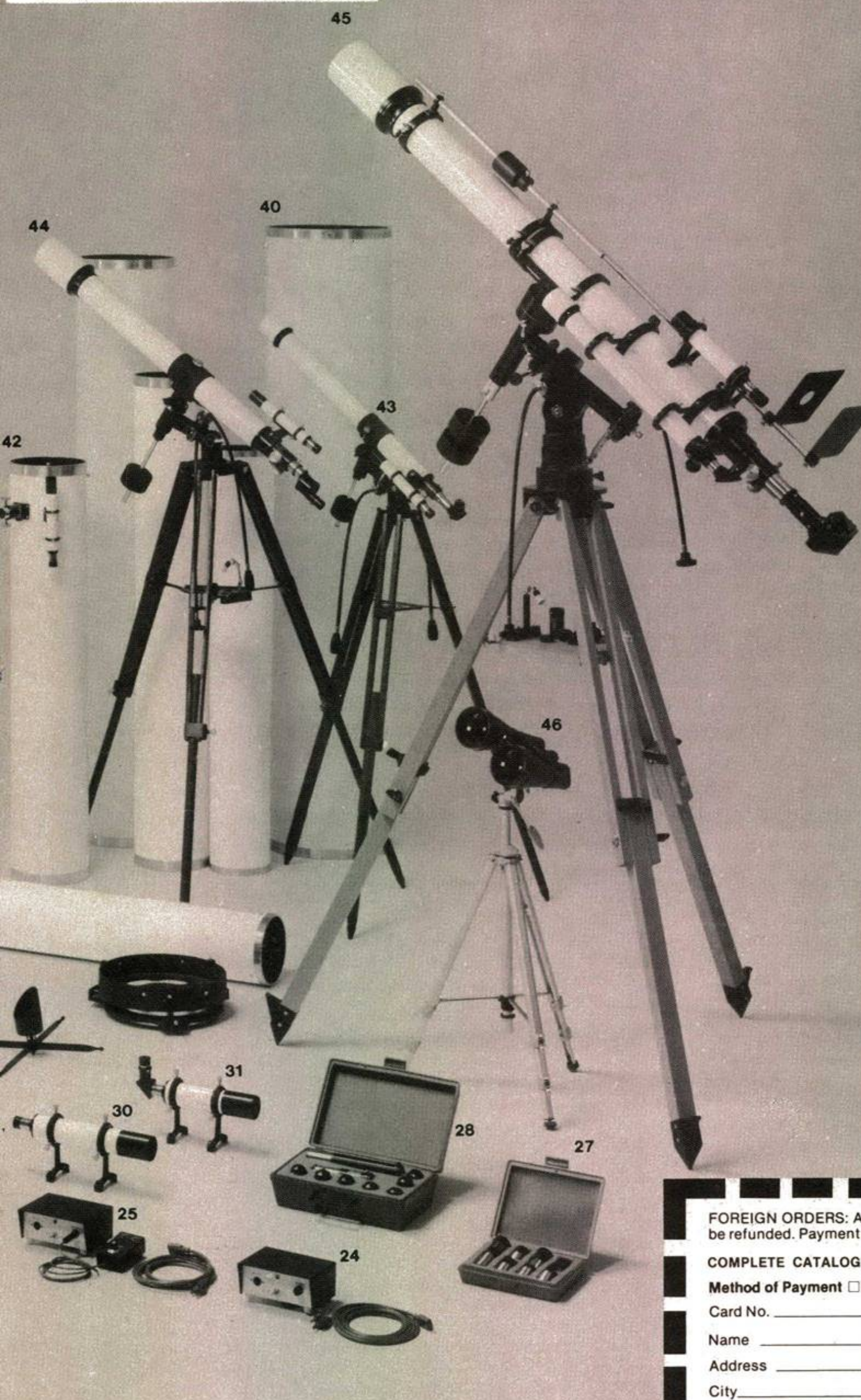

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GAZER'S GAZETTE

Observing Planetary Nebulae

by

Tom Reiland

Since the first planetary nebula was seen through the telescopes of the early 1700s, this class of celestial objects has been misnamed, misunderstood and misplaced by many observers. These tombs of suns that have reached the ends of their life cycles are forgotten objects when skywatchers compile lists of their favorite heavenly bodies.

The well-known observer Sam Brown, for instance, described planetaries as "just hazy dots in the sky", and suggested that observers without at least an eight inch telescope should avoid them. Other writers have made the mistake of omitting these nebulae from observing atlases because they lack the size and brightness of star clusters and galaxies.

Many observers make this common mistake. They take for granted the celestial wonders they view through their instruments will look just like photographs obtained at the major observatories. Even the most disciplined observers can be subconsciously influenced by both photographs and others' drawings.

But if this is the case, who wants to look at "hazy dots" that seldom resemble photographs? Why observe planetary nebulae at all, if so many experienced observers see fit to ignore them?

First, as a good observer, you will always accept the challenge of locating a difficult object. Finding a dim planetary nebula — or any other faint object — can help give you confidence in both your telescope and your observing ability.

Second, contrary to what has often been stated in the past, planetary nebulae offer surprising amounts of detail. They come in a great variety of shapes, types and colors — as can be attested to by their many nicknames. (More nicknames are attached to planetary nebulae than to any other class of celestial object.)

History and Description

Planetary nebulae are envelopes of gases that have been ejected from old stars. This separation occurs when a red giant of about one solar mass is about to enter the white dwarf stage of stellar evolution. The nebula is formed in the interval between these two stages. Planetary nebulae are born in much the same way as the expanding shells of gas given off by novae. The difference is one of velocity: Whereas a nova is a violent stellar outburst, a planetary nebula forms when a red giant collapses into a white dwarf and "puffs out" its outer shells in the process, leaving an expanding nebula and a very hot central star. A typical planetary nebula is moving outward at 15 miles per second.

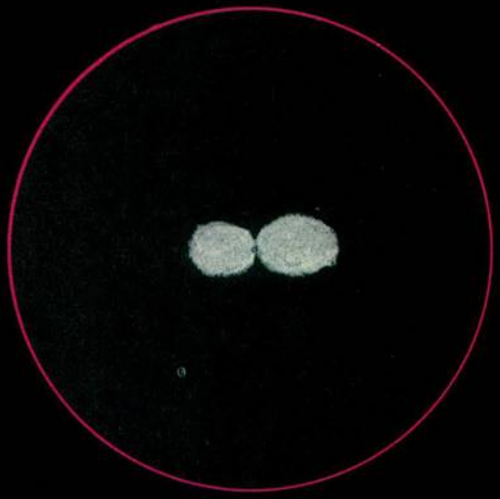
Astronomers can determine the velocity of a particular planetary by studying its spectrum, and thus can discover how long ago the outburst that formed the nebula took place. Most of the planetaries we see are about 20,000 years old; after about 100,000 years, the shell of gas has become too diffuse to see. Planetary nebulae are therefore temporary objects that will pass away in a short time (by the universe's standards). In contrast, globular clusters are many billions of years old!

The gases in the nebula, however, have nothing to do with the formation of planets, as some astronomers once theorized, nor is that the reason for the name "planetary nebula".

In 1781, English astronomer William Herschel discovered the planet Uranus. Four years later he noticed that many of the small, hazy nebulae he observed appeared to have greenish disks, similar to that of Uranus. Because of this similarity, Herschel, in his extensive catalog of deep sky objects, named

Planetary nebulae come in all shapes and sizes, as the drawings opposite show. Top left: NGC-6302 in Scorpius is called the Bug nebula and looks like two connected oval stars. It appears at its best in apertures of six inches or larger. Top right: NGC-7662 in Andromeda has a pale blue disk surrounding a dim central star; large apertures are recommended for this object also. Center left: NGC-2392 in Gemini, the Eskimo nebula, is bright and easily spotted in small instruments. Center right: NGC-2438 is a ring planetary that lies within the rich open cluster M-46 in Puppis. The nebula is actually much closer to us than the cluster, which merely lies along the same line of sight. Bottom left: IC-418 in Lepus is easy to locate because of its bright central star; the nebula is a bluish haze. Bottom right: NGC-3132 is a superb planetary nebula — virtually the only object of interest in the constellation Antlia. Drawings by Tom Reiland.

NGC-6302



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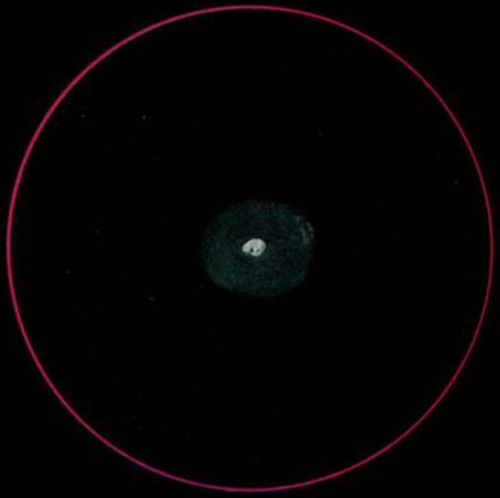
NGC-7662



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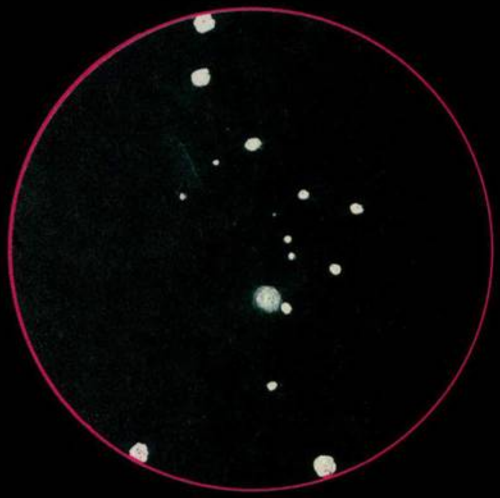
NGC-2392



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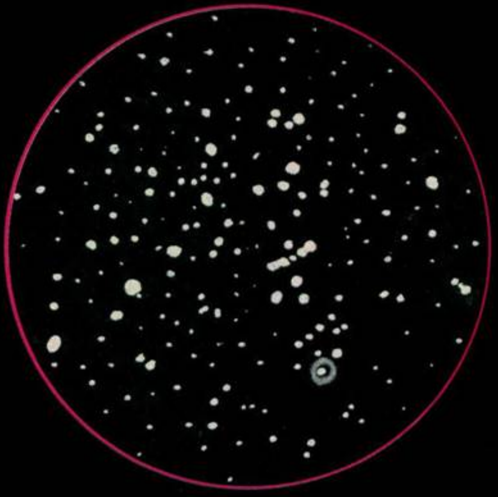
NGC-2438



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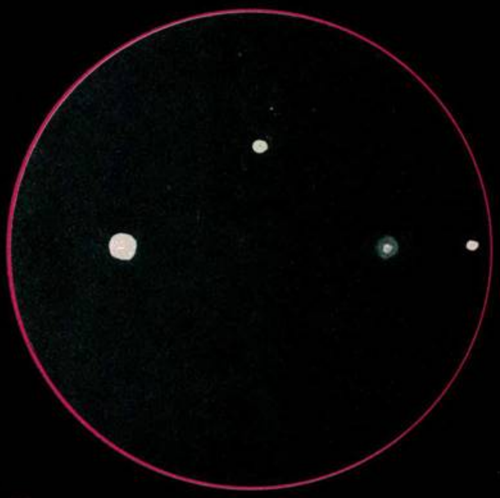
IC-418



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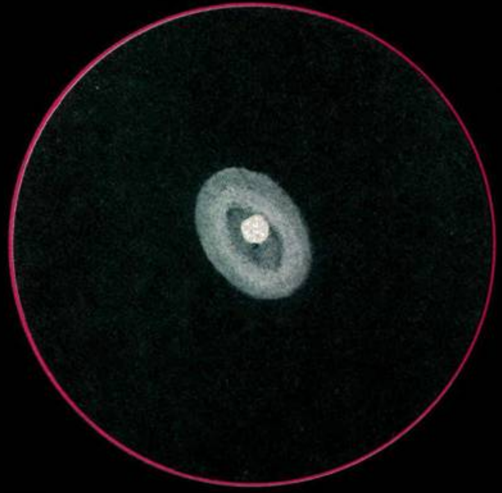
NGC-3132



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his fourth class of nebulae "planetary". It was his belief that these objects were very old and were undergoing a period of change. Herschel was not the first to notice this likeness, incidentally. French astronomer Darquier, in 1779, described M-57 (the Ring nebula) as "looking like a fading planet".

Location and Identification

Even the most curious observers may feel like turning their telescopes to the nearest bright star cluster after reading in various catalogs the low magnitudes of many planetaries! These estimates, however, are apparent *photographic* magnitudes; the visual magnitudes may be either brighter or dimmer than those measurements. Most often the nebulae are visually brighter, but there are a few exceptions. For example, NGC-7293 (the Helix nebula in Aquarius) is listed at magnitude 6.5, but because of its diffuseness and large size, its surface brightness is low and it's difficult to find with anything smaller than a four inch instrument — and then only on the best of nights. On the other hand, NGC-2440 in Puppis is estimated at magnitude 11.7, but because it's fairly small and condensed, it appears as a pale blue, eighth magnitude disk. So don't be discouraged by low estimated magnitudes; planetaries have lots of surprises in store!

The sizes of most planetaries, given in seconds of arc (galaxies and star clusters are listed in minutes of arc), make most of them fairly tough objects to locate and identify. Their compactness, however, allows you an opportunity to study their features at high magnification — something you often don't get with more extended objects.

Unless you own a good pair of setting circles and want to take the fun out of rediscovering each planetary, the best approach for finding these deep sky "untouchables" is by star hopping. Locate the closest bright star near the object you wish to find (preferably third magnitude or brighter). Now move from the star to where the nebula should be, hopping from one star to the next while all the time approaching the nebula.

Once you find the nebula, what can you expect to see? It all depends on its type and the brightness of its central star. If the star is brighter than the nebula, you'll see a faint glow around the star; usually, however, the nebula is brighter.

The majority of planetaries are blue, blue-green or greenish oval shaped disks. Other disks may look gray, blue-gray or white; the more diffuse planetaries will have an off-white or gray-white color, giving them a ghostly or phantom appearance. Some areas of these less concentrated nebulae will be brighter than others. This type of planetary comes in many different shapes and sizes, often larger than the typical blue disks.

The final method for separating planetaries from stars is to use high magnification on the object you lock onto. If you see diffraction rings, it's a star; if you don't, you've found your nebula.

How large a telescope do you need to find these "fuzzy dots"? If you use a 2.4 inch refractor, you can expect to find about 20 planetaries. The number will increase with the greater light gathering power of larger instruments. A six inch f/8 reflector is capable of locating 50 to 70 planetaries.

Four planetaries are found in the Messier catalog: M-27 (the Dumbbell nebula) in Vulpecula, M-57 (the Ring nebula) in Lyra, M-76 (the Barbell nebula) in Perseus, and M-97 (the Owl nebula) in Ursa Major. (Photographs of these objects are on pages 46 and 47 .) These nebulae are all famous by virtue of their inclusion in the Messier list, and descriptions of the four abound in literature. Therefore, the planetary nebulae discussed below are those which you are less likely to see described elsewhere; many of them are just as bright or interesting as the four Messier planetaries.

A fifth object, M-1 (the Crab nebula in Taurus), is often included in lists of planetary nebulae because it fits into no other category. Actually, M-1 — as is well-known — is the remnant of the supernova of 1054, and is a planetary nebula only by "courtesy".

Summer

Besides the Dumbbell and Ring (the most famous and probably the best of the planetary nebulae), summer skies offer a wide selection of different planetaries. In the tail of Scorpius, about three degrees west of Lambda (λ) and Upsilon (υ) Scorpii, is an unusual nebula classified as both planetary and diffuse. This odd looking object, NGC-6302, is known as the Bug nebula. It consists of two sections, much like M-27; however, its two white, nebulous areas are more compact and oval than the Dumbbell's. The nebula is easy in a four inch reflector and looks like two elongated stars, connected like the head and body of a beetle. NGC-6302 is among the more unusual planetaries, so don't ignore it.

Probably one of the finest examples of a true planetary is NGC-6818 in Sagittarius. This pale blue disk was described by Webb as a "star out of focus"; Mallas called it the "little gem" and noted that it was the bluest of the planetaries he had observed. ASTRONOMY contributing editor James Mullaney has stated that NGC-6818 is "starlike in a three or four inch scope with low power, but shows a minute disk when highly magnified". NGC-6818 can be found about two degrees north of 54 and 55 Sagittarii; it is just one degree north of the galaxy NGC-6822.

Among the many other planetary nebulae visible during the summer are NGC-6210 in Hercules (see Star Dome, August 1976); NGC-6543 in Draco (Star Dome, April 1976); NGC-6572 in Ophiuchus (Star Dome, June 1977), and NGC-6905 in Delphinus, featured in this month's Star Dome.

The 35 Finest Planetary Nebulae

Object	R.A. (1950)	Dec.	Mag.^{n}	Mag.^{s}	Size	Type	Constellation	Nickname
NGC-40	0^h10^m	+72°15'	10.2	11.4	60"x38"	Oval	Cepheus	
NGC-246	0^h45^m	−12°09'	8.5	11.3	240"x210"	Oval	Cetus	
M-76	1^h39^m	+51°19'	12.2	16.6	157"x87"	Irr.	Perseus	Barbell
NGC-1535	4^h12^m	−12°52'	9.3	11.8	20"x17"	Oval	Eridanus	
IC-418	5^h25^m	−12°44'	12.0	10.9	14"x11"	Ring	Lepus	
M-1	5^h32^m	+21°59'	8.4	15.9	360"x240"	Irr.	Taurus	Crab
IC-2149	5^h53^m	+46°07'	9.9	14.0	15"x10"	Oval	Auriga	
NGC-2392	7^h26^m	+21°01'	8.3	10.5	47"x43"	Oval	Gemini	Eskimo
NGC-2438	7^h40^m	−14°36'	11.3	16.8	68"	Ring	Puppis	
NGC-2440	7^h40^m	−18°05'	11.7	16.5	54"x20"	Oval	Puppis	
NGC-3132	10^h05^m	−40°11'	8.2	10.6	84"x53"	Ring	Antlia	Eight-Burst
NGC-3242	10^h22^m	−18°23'	9.0	11.4	40"x35"	Oval	Hydra	Ghost of Jupiter
M-97	11^h12^m	+55°18'	12.0	14.3	203"x199"	Oval	Ursa Major	Owl
NGC-4361	12^h22^m	−18°29'	10.8	12.8	81"	Oval	Corvus	
IC-3568	12^h32^m	+82°51'	11.6	12.0	18"	Oval	Camelopardalis	
IC-4593	16^h10^m	+12°12'	10.2	10.2	15"x11"	Oval	Serpens Caput	White-Eyed Pea
NGC-6210	16^h43^m	+23°53'	9.7	12.5	20"x13"	Oval	Hercules	
NGC-6302	17^h10^m	−37°03'	11.4	—	120"x60"	Irr.	Scorpius	Bug
NGC-6309	17^h11^m	−12°51'	11.6	14.1	19"x10"	Oval	Ophiuchus	
NGC-6369	17^h26^m	−23°44'	9.9	16.6	28"	Ring	Ophiuchus	Little Ghost
NGC-6543	17^h59^m	+66°38'	8.8	11.1	22"	Oval	Draco	Cat's Eye
NGC-6572	18^h10^m	+06°50'	9.6	12.0	16"x13"	Oval	Ophiuchus	
NGC-6629	18^h23^m	−23°14'	10.6	13.6	16"x14"	Oval	Sagittarius	
M-57	18^h52^m	+32°58'	9.3	14.7	83"x59"	Ring	Lyra	Ring
NGC-6781	19^h16^m	+06°26'	12.5	15.4	106"	Oval	Aquila	
NGC-6818	19^h41^m	−14°17'	9.9	15.0	22"x15"	Oval	Sagittarius	Little Gem
NGC-6826	19^h43^m	+50°24'	8.8	10.8	27"x24"	Oval	Cygnus	Blinking Planetary
M-27	19^h57^m	+22°35'	7.6	13.4	480"x240"	Oval	Vulpecula	Dumbbell
NGC-6891	20^h13^m	+12°35'	11.4	11.6	15"x7"	Oval	Aquila	
NGC-6905	20^h20^m	+19°57'	11.9	14.2	44"x37"	Oval	Delphinus	Blue Flash
NGC-7009	21^h01^m	−11°34'	8.4	11.7	44"x26"	Oval	Aquarius	Saturn
NGC-7027	21^h05^m	+42°02'	10.4	17.1	18"x11"	Irr.	Cygnus	
NGC-7048	21^h13^m	+46°04'	11.3	18.3	60"x50"	Oval	Cygnus	
NGC-7293	22^h27^m	−21°06'	6.5	13.3	900"x720"	Ring	Aquarius	Helix
NGC-7662	23^h24^m	+42°14'	8.9	12.5	32"x28"	Oval	Andromeda	

Mag.^{n} = Magnitude of nebula
Irr. = Irregular

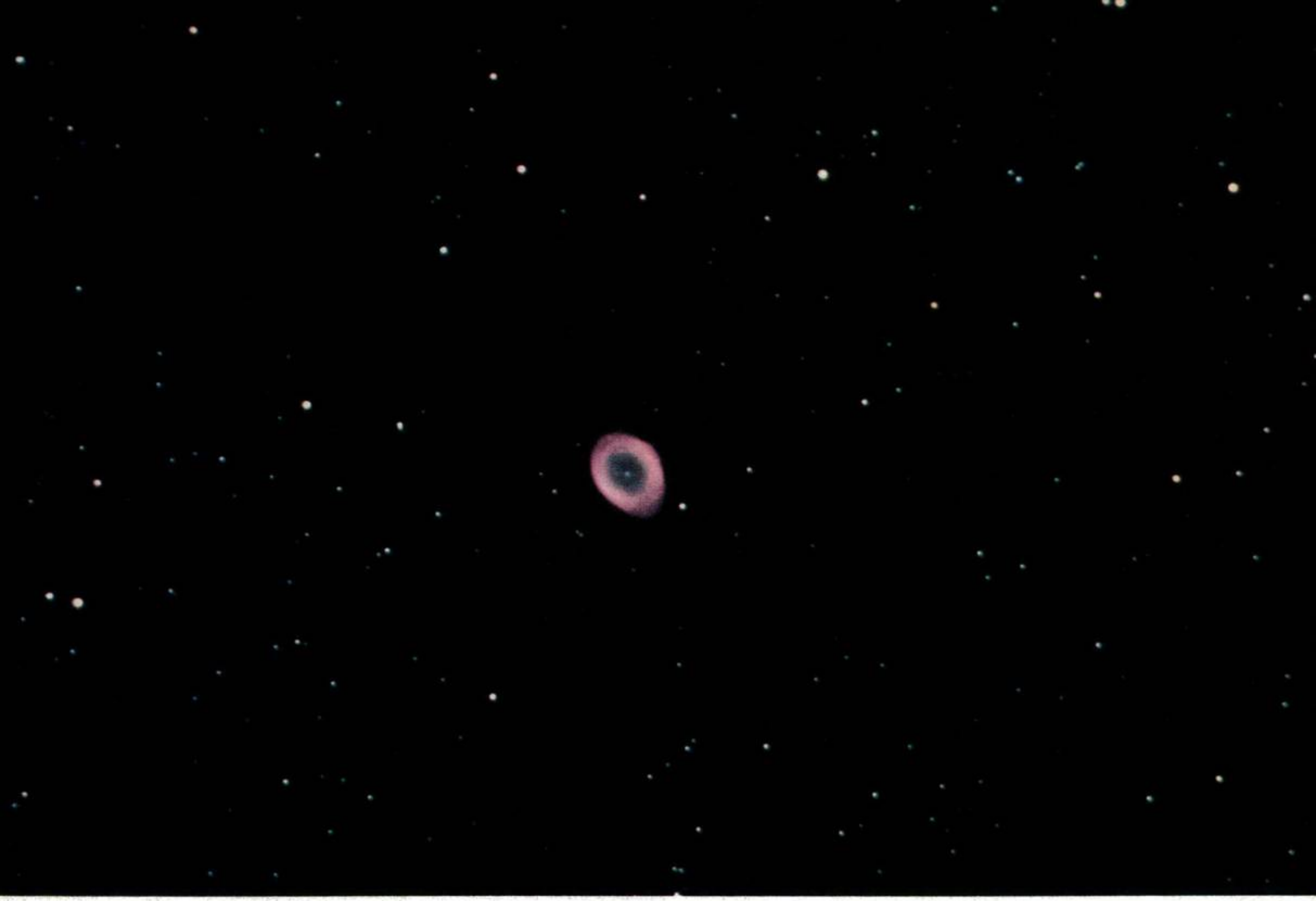
Mag.^{s} = Magnitude of star
A blank in a column indicates quantity unknown

Some Difficult Planetary Nebulae

Object	R.A. (1950)	Dec.	Mag.^{n}	Mag.^{s}	Size	Type	Constellation	Nickname
NGC-1501	4^h03^m	+60°47'	13.3	13.4	56"x48"	Oval	Camelopardalis	
NGC-1514	4^h06^m	+30°38'	10.8	9.7	120"x90"	Irr.	Perseus	
NGC-2022	5^h39^m	+09°03'	12.8	14.6	28"x27"	Ring & Oval	Orion	
NGC-2371-2	7^h22^m	+29°35'	13.0	13.3	54"x35"	Irr.	Gemini	
NGC-2452	7^h46^m	−27°13'	12.6	19.0	22"x16"	Ring	Puppis	
IC-4406	14^h19^m	−43°55'	10.6	—	100"x37"	Oval	Lupus	
NGC-6445	17^h46^m	−20°00'	13.2	19.1	38"x29"	Oval	Sagittarius	Crescent
NGC-6741	19^h00^m	−00°31'	11.7	16.7	9"x7"	Ring	Aquila	Phantom Streak
NGC-7008	20^h59^m	+54°21'	13.3	12.9	86"x69"	Oval	Cygnus	
NGC-7635	23^h19^m	+60°54'	8.5	8.5	205"x180"	Irr.	Cassiopeia	Bubble

Mag.^{n} = Magnitude of nebula
Irr. = Irregular

Mag.^{s} = Magnitude of star
A blank in a column indicates quantity unknown



Fall

The famous Saturn nebula, NGC-7009, was the first object listed in William Herschel's class of planetary nebulae. Just three degrees east-northeast of M-72 and M-73, NGC-7009 shows up as a solid, chalky blue disk in a six inch reflector at 170 power. This magnification allows the observer to see two areas of brightness: a central concentration that is elliptical and bright, and an outer region that is more diffuse and oval. The outshoots of the nebula that give NGC-7009 its name are visible only in photographs. The Saturn nebula is 1-1/2 degrees west of Nu (ν) Aquarii.

Farther north, and surrounded by some of the finest celestial showpieces in the northern hemisphere, is NGC-7662 — seldom observed during scans of the constellation Andromeda. It's easy to locate this ninth magnitude planetary even in 10 x 50 binoculars. In a six inch telescope at 50 power, NGC-7662 looks like a small, blue disk; smaller instruments will show a pale, "out of focus" star. If you use a six inch reflector with high magnification, you'll see the central star that Barnard thought was a variable. NGC-7662 is located just south of 13 Andromedae and two degrees west of Iota (ι) and Chi (χ) Andromedae.

NGC-40 in Cepheus will be more difficult to locate. It's about six degrees south-southeast of Gamma (γ) Cephei and 10 degrees north-northeast of Chi (χ) Cassiopeiae. NGC-40 has a bright central star, with a brighter inner nebula and faint outer nebulous rings.

The three planetary nebulae shown in these photographs are among four included in the Messier catalog. Above: M-57, the Ring nebula in Lyra, is one of the most immediately distinctive of all celestial objects; it can be seen even in a three inch telescope. The 15th magnitude central star is visible only with very large aperture instruments. This photo is a 20 minute exposure on High Speed Ektachrome, made through a 14 inch Schmidt-Cassegrain at f/11. Photograph by Leo C. Henzl Jr. Opposite page, left: M-97, the Owl nebula, is so called from the two dark regions in its disk, thought to resemble an owl's eyes. M-97 is small and faint, located just beneath the bowl of the Big Dipper. This is a 50 minute exposure on 103aF film. Opposite, right: This 45 minute exposure on 103aF shows M-76 in Perseus, the faintest of all objects on the Messier list. Both of these photos were made with an eight inch Schmidt-Cassegrain at f/5. Photographs by Bill Iburg.

Winter

Though all planetary nebulae have characteristics of their own, there are at least two members of this group that could be mistaken for globular clusters. One is NGC-40, mentioned above; the other is NGC-2392 in Gemini. It has a bright central star surrounded by equally bright nebulous rings with dimmer outer rings. The outer portions of NGC-2392 are more diffuse than the compact central rings — just as a globular cluster is brighter at its center than near its edges. This globular

appearance is not unlike that of the head of a small comet, and it amazes many astronomers that Messier (who compiled his catalog during his comet searches) missed this nebula.

NGC-2392 is nicknamed the Eskimo nebula. Webb was so amazed at the excellence of this blue-white nebula in his 3.7 inch refractor that he compared it to "either damp on the eye lens or a telescopic comet". Look about two degrees east-southeast of Delta (δ) Geminorum to locate the Eskimo. It's visible in a 7 x 50 finderscope, and easy in a 2.4 inch refractor.

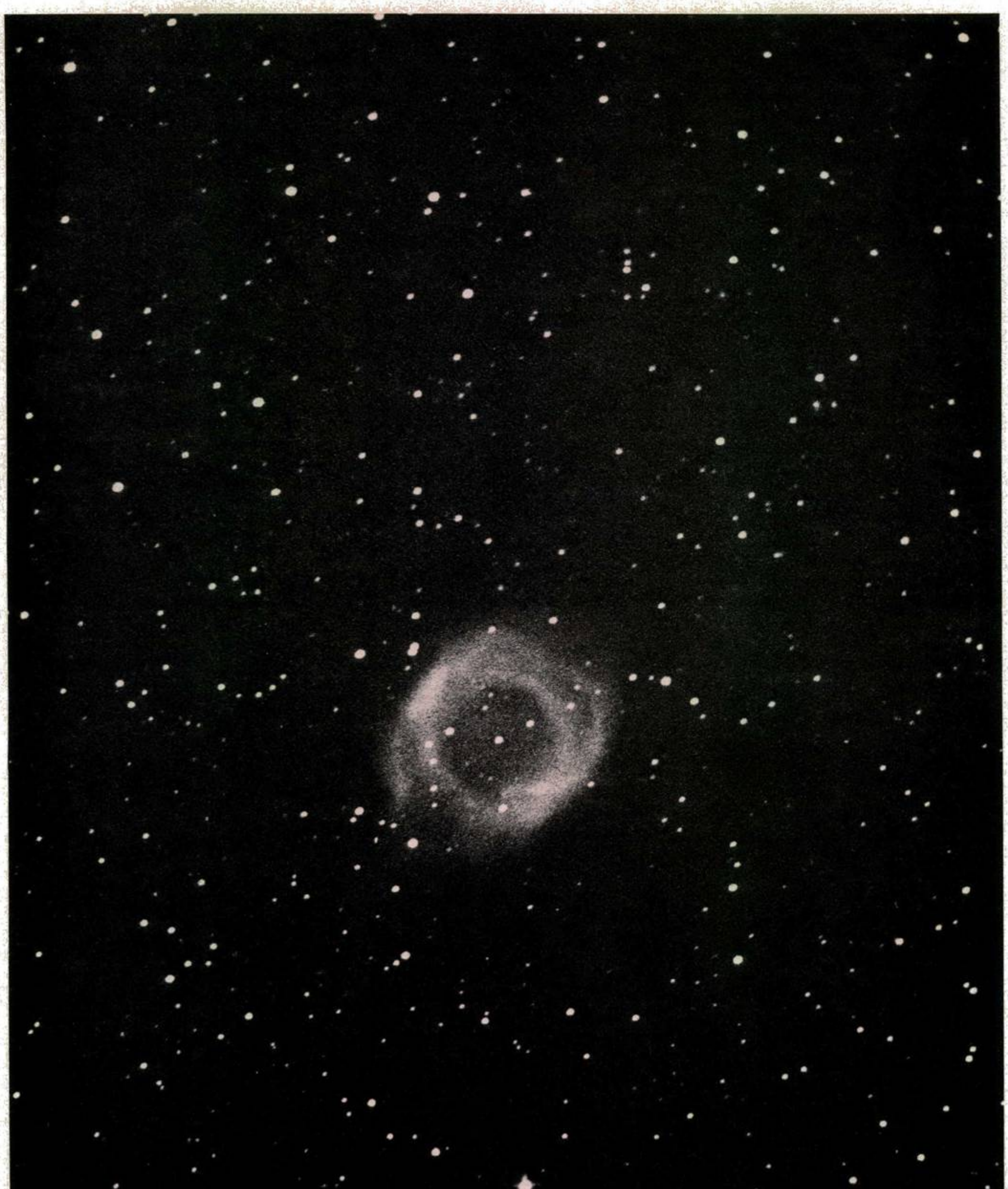
Though much dimmer than its neighbor, NGC-2371-2 (also in Gemini) is a fine test object for seeing conditions and four inch telescopes. Mallas was able to glimpse this 13th magnitude planetary with his four inch, but only on the best of nights. A six inch reflector is recommended to see the dumbbell shape of NGC-2371-2. You should use averted vision on this dim, ghostly nebula and its 13.3 magnitude central star. The star seems to flicker in and out of view, as if the two sections of the planetary were wings of a butterfly flitting back and forth. To find NGC-2371-2, use the stars 65 and 64 Geminorum as pointers, and look about 1-1/2 degrees northwest of them.

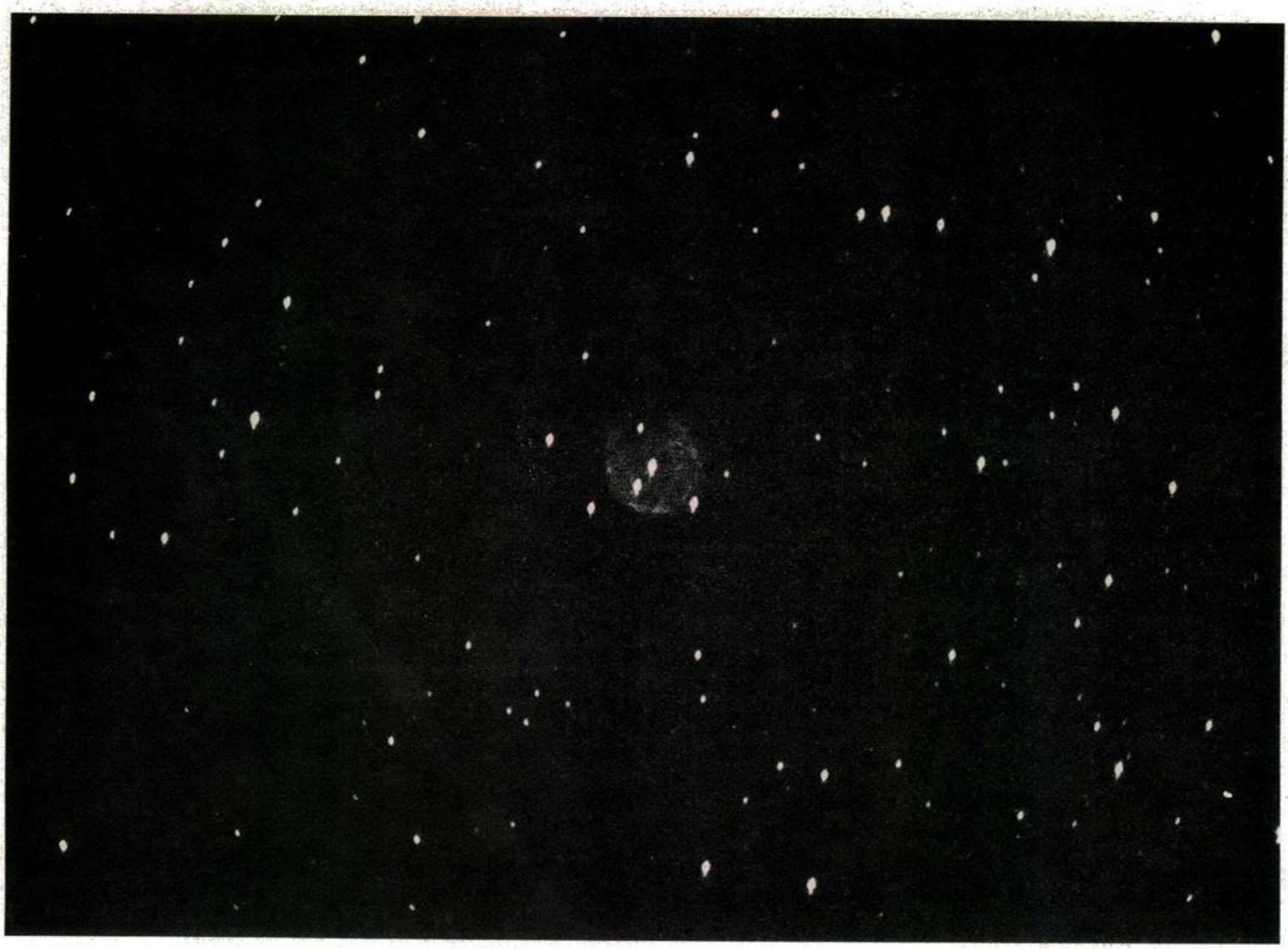
In the southern constellation Puppis are three planetary nebulae within the reach of a six inch reflector. NGC-2440, described earlier, is probably the finest of these. To locate it, look three degrees south of M-46. After you locate NGC-2440, go back to M-46 and scan the northern edge of this fine open cluster. A three inch refractor at 78 to 120 power can bring in the dim, white ring nebula, NGC-2438. Even in a six inch scope, this object illustrates the pulsating, ghostly image commonly seen in many planetaries. The nebula is actually much closer to us than the open cluster in which it is apparently located.

About 13 degrees south of this deep sky duo is a similar pair. Touching the southern edge of the small, dim open cluster NGC-2453 is another miniature ring, NGC-2452. This 12.6 magnitude nebula has the same characteristics as NGC-2438, but it's somewhat dimmer and smaller. If you use a six inch at 120 power on a clear, transparent night, you'll get a glimpse of this elusive, white ring nebula. M-93, located three degrees north of this pair of objects, makes a good stepping stone to NGC-2452.

Planetary nebulae with the IC (Index Catalog) designation are the most neglected of all because they are often considered inferior to those on the NGC listing. There are, however, at least a half dozen worth viewing through a four inch.

IC-418 in Lepus is one such object. It appears





Opposite: NGC-7293, the Helix nebula in Aquarius, is the largest of all planetary nebulae. Because of its extended size, its surface brightness is low and it is fairly difficult to see. This 30 minute exposure on 103aF film was obtained with a home built eight inch f/5 Newtonian reflector. Photograph by Walter Hamler. Above: NGC-246 is a planetary nebula in Cetus; it is described by the NGC as "very faint, large, with four stars in diffuse nebula". Both NGC-246 and NGC-7293 are highest during the autumn. This is a 40 minute exposure on 103aF film, made with an eight inch Schmidt-Cassegrain at f/5. Photograph by Bill Iburg.

as a round, hazy glow covering an 11th magnitude central star. Mallas described this pastel blue planetary as "a halo around the star . . . oval in shape". Located just below Orion, IC-418 forms a trapezoid with Nu (ν), Lambda (λ) and 8 Leporis, and is easily identified in a four inch instrument at 50 power.

Spring

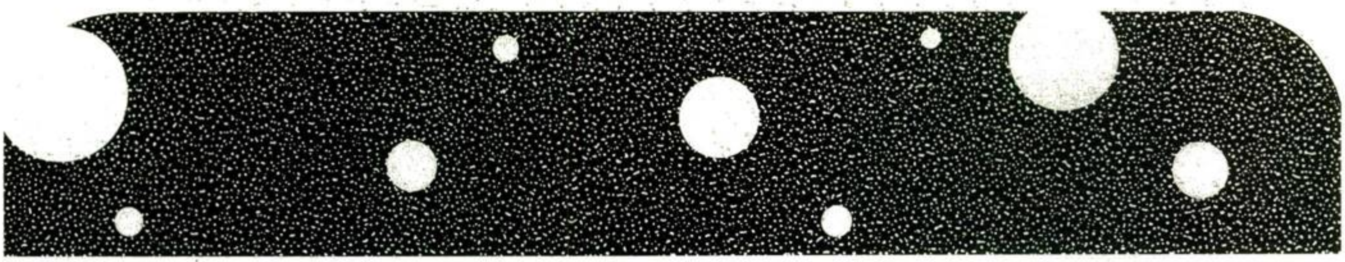
Because most planetaries — like most clusters and diffuse nebulae — are located along the Milky Way, there are fewer visible during the spring than in any other season. One that is definitely worth the search is NGC-3132, located in Antlia. NGC-3132 is a ring nebula that surpasses M-57 in detail and brightness. Nicknamed the Eight-Burst, NGC-3132 is a soft, blue-white nebula. This oval or egg-shaped object surrounds a bright, 10th magnitude central star. A more appropriate name might be the Easter Egg nebula.

Though not well-known (probably because of its far southern declination), NGC-3132 must rank as one of the 10 finest planetaries. The drawing on page 43 of this object was made on an exceptional night when seeing and transparency were excellent.

Locating NGC-3132 will be difficult because of its southern location and the lack of bright stars in the constellation Antlia. Try waiting for Regulus in Leo to reach the meridian, and then direct your telescope 52 degrees south of that star. Before you try, however, we recommend you obtain a good star map before you seek out this or any other dim object. Also, check out NGC-3242 in Hydra (described in Star Dome, May 1975 and March 1977).

The rewards you will harvest from making a survey of planetary nebulae will come from the search itself. As each new object reveals itself, you'll experience an amazing variety with these little known nebulae. Each is unique, with its own special wonders. Most important of all is the sheer enjoyment of the search.

Tom Reiland is currently the president of the Amateur Astronomers Association of Pittsburgh. He is a specialist in the observation of planetary nebulae, globular clusters and other deep sky objects. He recently observed 103 Messier objects in a single night!



STELLAR FRONTIERS

Does the Universe Oscillate?

by

John Gribbin

Few astronomers now doubt that the universe originated in a big bang, the violent initial outburst which has left behind a faint echo — the cosmic microwave background radiation — and a universe in which all the galaxies and clusters of galaxies are moving apart. Everything in the expanding universe apparently started out from the same place and time about 20 billion years ago. Ever since, the fragments of that initial creation event have been flying apart. The main pieces — those which reveal this motion — are galaxies and clusters of galaxies, swept along on the expansion of spacetime; within galaxies, the movement of our sun through space, or of Earth around the sun, are simply of too small a scale to be affected.

Although almost all cosmologists are happy with this picture, it poses one uncomfortable question: What was there *before* the big bang? The standard answer — that the question lies outside the scope of cosmology — begs the issue; whether you call it cosmology, philosophy or religion, the question can still be asked. And although no consensus has emerged, there are several plausible answers around which can satisfy the philosophers, while retaining the features of the big bang that make that model so attractive to cosmologists.

First, we need to have some understanding of the nature of spacetime, and what that big bang event really meant. Most people encountering the concept for the first time imagine all the matter of the galaxies collected in some great superstar or supergalaxy in the middle of empty space, which exploded outward into the void. But that picture is completely false.

Not just matter, but space and time as well, were wrapped up in the singularity — a mathematical point — from which the universe began its expansion. The material didn't move outward into the void, simply because *void* itself was created in the big bang, and has itself been expanding ever since!

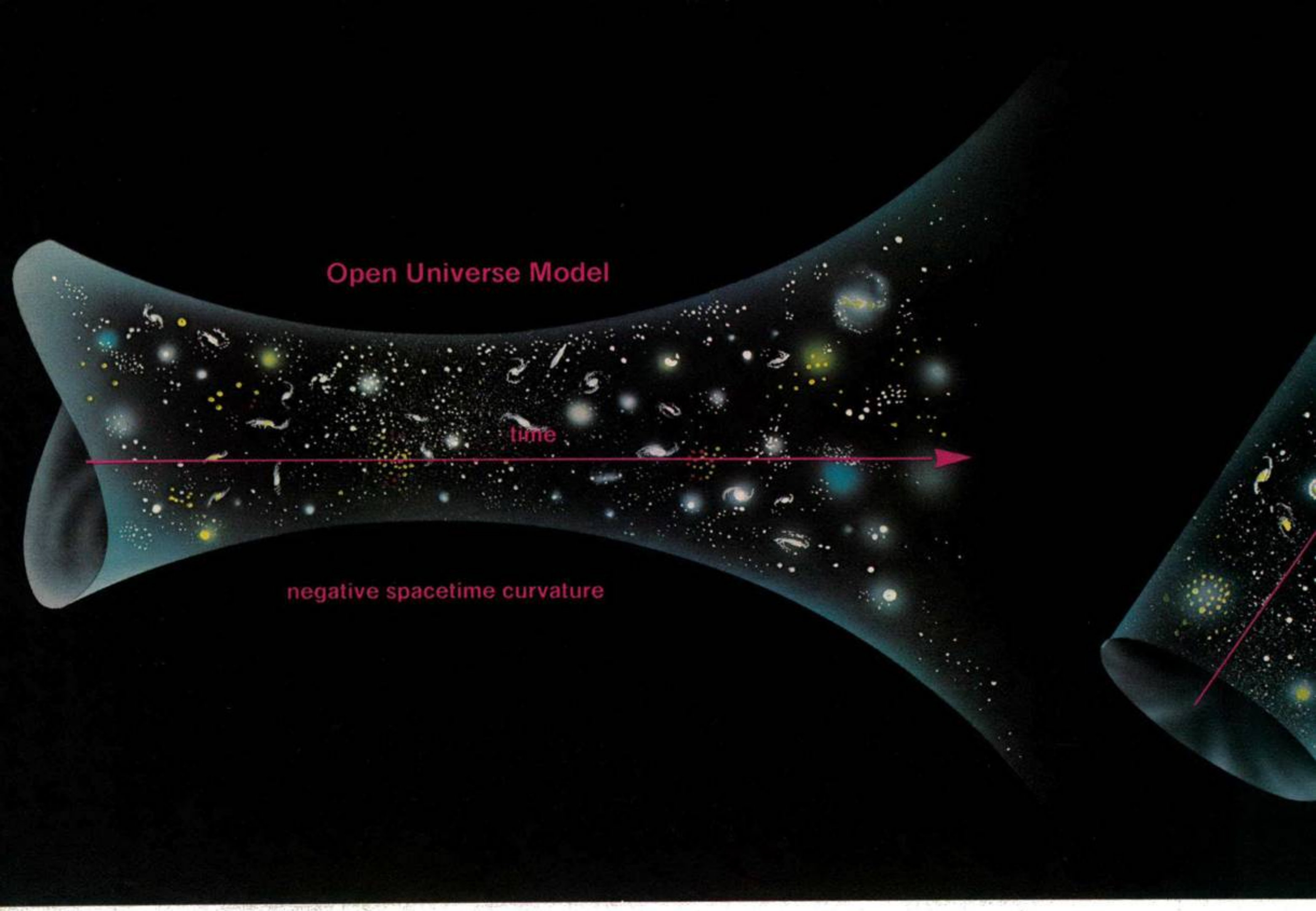
In the equations of relativity theory, from which modern cosmological theories develop, it is the void itself — *spacetime* — that is described. The matter in the universe is just an incidental extra; the real universe *is* spacetime. The recession of the galaxies that we see in the expanding universe is not a result of their movement through the fabric of spacetime, but a result of the fabric expanding and carrying them along with it! It's just like a series of dots painted on a piece of rubber — if you stretch the rubber sheet, the dots move farther apart. They do not move around on the rubber sheet itself.

This is the great revolution in 20th century thought begun by Einstein — the exciting notion that spacetime could be stretched or curved, and that disturbances that are felt by matter (such as gravity) are a result of this bending of spacetime. The reason why Earth moves around the sun is seen in this picture as a result of the curvature of spacetime. Instead of moving in straight lines through empty space, the planets follow the equivalent of straight lines — called *geodesics* — in curved space. Again, the old rubber sheet analogy provides a neat physical insight into what this means (see illustration on page 54).

A massive, dense sphere in the middle of such a stretched sheet bends the spacetime of the rubber — in fact, it's curved into a funnel-like shape. Smaller spheres that are rolled across the sheet will be deflected by this curvature, just as planets moving near the sun are deflected by its gravity. Furthermore, light itself is also bent along the curved surface of spacetime! These effects have been proven by measuring the bending of light from distant stars as it passes near the sun, and most recently (and most accurately) by measuring the bending of radio signals from the Viking landers as Mars moved behind the sun. The effect is undoubtedly real, and that means we must take Einstein's physics seriously when applied to the curvature of the universe itself.

Although Einstein's equations can't really describe a universe full of matter very easily, that is no problem: After all, our universe is *very nearly empty!* The space between stars, and between galaxies, is a vastly greater part of space than the small

The distant galaxies and clusters of galaxies are receding from us at enormous speeds: the farther away they are, the faster they are moving. This cluster of galaxies in Hercules (taken with the 200 inch telescope at Hale Observatories) is receding from us at more than 10,000km per second — somewhat in excess of 20,000,000 m.p.h.! By measuring the shift in the position of features in the spectrum of a galaxy, astronomers can measure this speed quite accurately. Such measurements are the raw data of cosmology. Hale Observatories photograph.



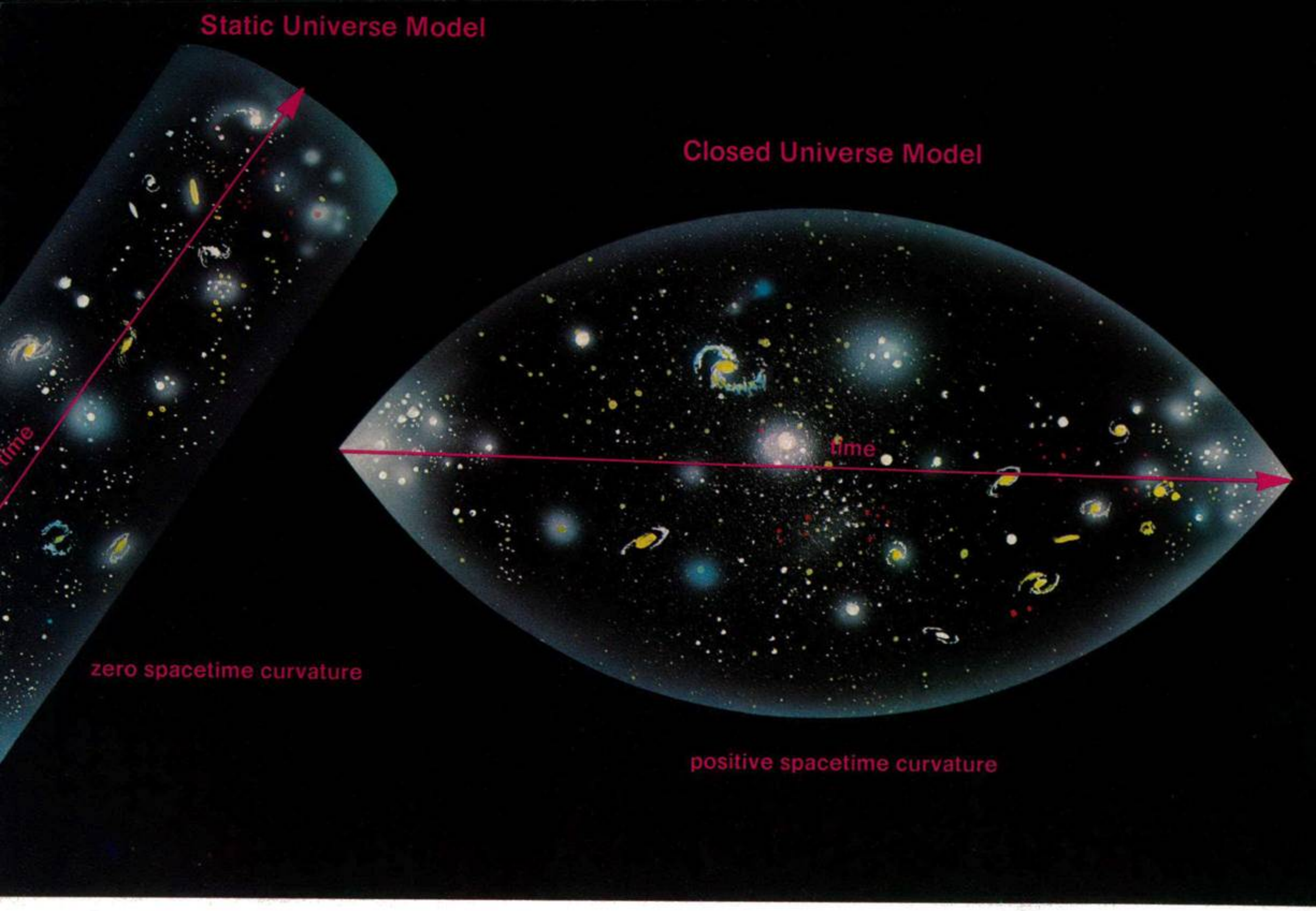
volume where matter exists in any quantity. Even the spaces between atoms and inside atoms are mostly empty space. So when cosmologists apply Einstein's equations to predict how the universe might behave, they can happily use the equations as they would apply to a nearly empty void, with a smoothed out smattering of matter to be carried along "for the ride" by the distortions of spacetime. What they find is that, in principle, our universe is not unique. There are different solutions to the equations, each corresponding to a different kind of universe — and one of those solutions seems to be the expanding universe we live in.

In general, there are two kinds of solutions, equivalent to universes with "positive" or "negative" spacetime curvature. Imagine a cylinder of spacetime (see illustration on this page). If we mark time by the long axis of the cylinder, then we can wrap space around, like the outside of a can. Everywhere in time the radius of the can is the same. If we glide down the cylinder through time, the curvature of the cylinder stays the same. But the real universe is not like that; observations of distant galaxies show the universe expands! Spacetime must be curved!

Now imagine a football with a line through the ends marking the axis of time. If we start at one tip of the football and follow the time axis to the other end, we see the surrounding space changing. The radius increases until we reach the middle, and then reduces back to zero at the other end. This is *positive curvature*, giving a *closed universe* model. The alternative is *negative curvature*, giving an *open universe*, with the narrowest spot in the middle and expansion infinite in both directions. The equations say that one of these families of possibilities must apply to the real universe.

But how can we tell which? In both kinds of universe there are times when the model expands, so the observation that our universe expands does no more than confirm that the *static* model (the straight cylinder) is a bad description of reality. There's a very simple test for positive or negative curvature on a *two dimensional surface*. On a flat piece of paper, the angles of a triangle always add up to 180 degrees (remember that from seventh grade?). On a closed surface curved like a sphere, the angles add up to *more* than 180 degrees, while on an open curved surface the sum is always *less* than 180 degrees.

In the three dimensions of the universe we live in, an equivalent test is to measure how the volume of a sphere changes as its radius increases. Using "number counts" of galaxies at great distances into space, astronomers can see successively larger spheres centered around our own galaxy. If we found the volume of such spheres increasing faster than it ought to, we would know space to be negatively curved; if the volume increases more slowly than it ought to, the curvature is positive. But the issue

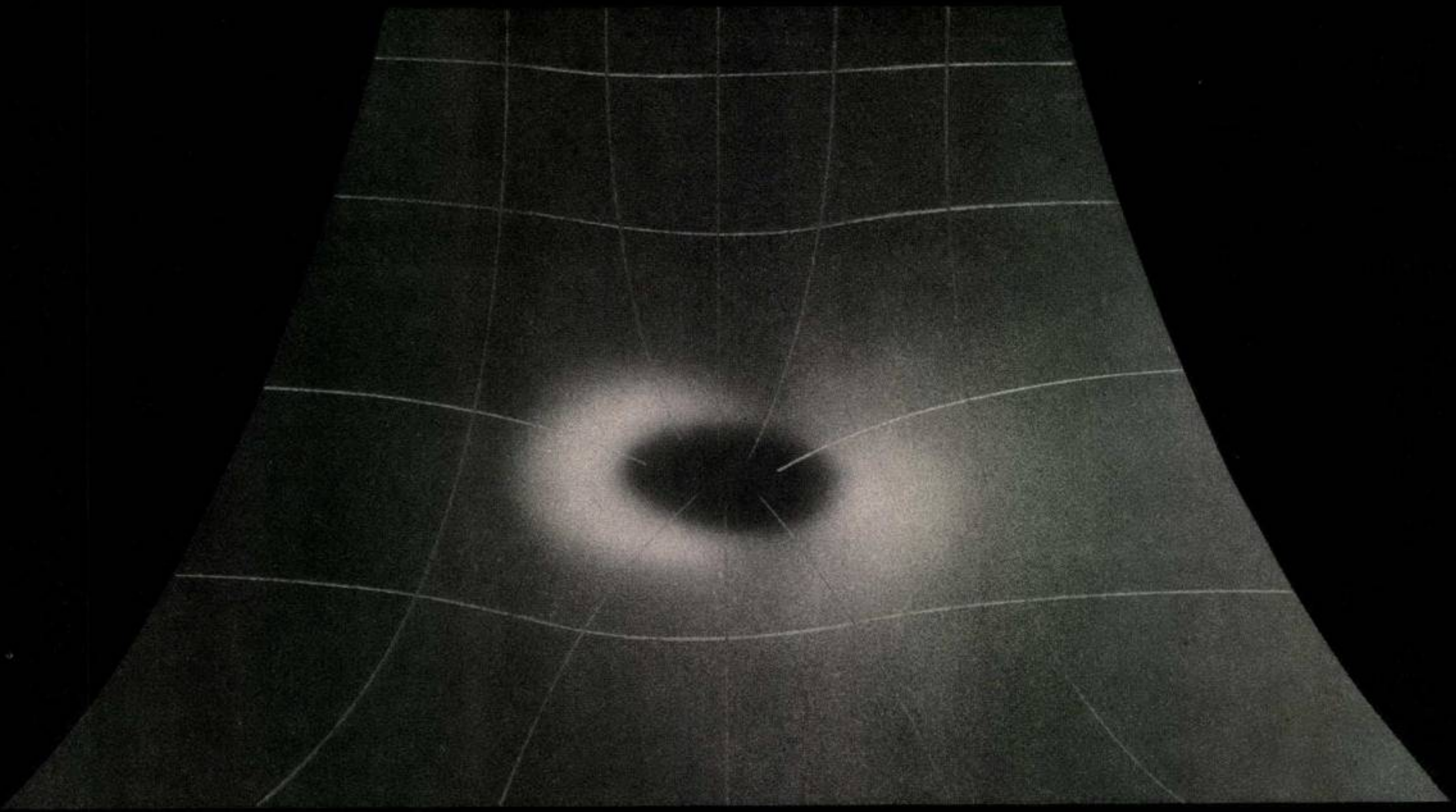


has yet to be finally settled, because the observations are so difficult.

Most cosmologists accept that the evidence we have leans on the side of negative curvature — that is, *an open universe in which expansion must continue forever.* But the observations are inconclusive, and leave enough room that we can still speculate about a closed universe, where we have yet to reach the maximum expansion, before the inevitable contraction that must follow. The observations definitely tell us that either way — negative or positive — our universe exists very close to the boundary between being closed and open. It is either *just* open, and will expand ever more slowly, forever, or it is *just* closed and will recollapse only with difficulty. If the case were really clear cut, we'd already know for sure! In itself, near equilibrium is an interesting feature of the universe, which any satisfactory cosmology ought to be able to explain.

But what does all this tell us about events before the big bang — before the beginning of time? Let's look again at the conventional picture of universal expansion (not forgetting that everything we describe is merely a symptom of the curvature of spacetime). In an open universe, forever expanding away from the big bang, the situation is like an exploding shell in which the fragments move faster than the escape velocity appropriate for their total gravitational mass. If you shoot a rocket up from Earth with more than escape velocity and it keeps going, Earth's gravity cannot pull it back. Explode the whole Earth with such force that each chunk of debris has at least this velocity, and all that remains would be an expanding asteroid cloud. Explode a whole universe in this way — you get the picture: It keeps on going.

But suppose the explosion was a bit less violent, so that the steady, persistent tug of gravity is sufficient to slow down the expansion, halt it, and then drag the bits back together again. This is like the closed universe model we discussed and, while it may not tell us what came before the big bang, it certainly tells us where the universe is going — back together! Such a collapse, on the grandest possible scale, is just what we need to produce a black hole, with matter (and spacetime) squeezed out of existence into a singularity. The opposite event — the big bang itself — is then seen as the equivalent outward event: a white hole (see "Black Holes, White Holes and Wormholes", ASTRONOMY, November 1976). If the material universe we know would start out from a singularity once, couldn't it do it again — with some kind of "bounce" at the ultimate black hole singularity switching things back into expansion? That is the basis of cyclic universe models in which the universe repeats itself, suggesting that what came before the big bang was simply a previous cycle of expansion and contraction, with another before that, and so on.



The rubber sheet analogy makes gravitational distortion of space easier to understand. In this analogy, space is likened to a two-dimensional rubber sheet: Beings living in the two-dimensional universe know nothing about a third dimension. Now imagine a massive object distorting their space, warping it "downward". For beings confined to the two-dimensional sheet, the space in the vicinity of the massive object is not normal. Diagram by Mark Paternostro.

The idea has great appeal, with the universe reborn like the phoenix from the fires of its own death. No longer must we worry about the creation of the universe, since there never was any unique creation event. Some pictures of the cyclic universe even explain why our universe is so near to the boundary between being open or closed.

In 1975, theorists David Park and P.T. Lansberg improved the standard cosmological equations. They now account for a complete universe — not just a void with a smear of matter in it, but also one filled with radiation like the cosmic microwave background. Their models incorporate the best features of standard cosmology (mainly about gravity) with features of the theory of thermodynamics (about the behavior of matter and radiation). The result is a hybrid. Park and Landsberg, themselves, describe their equations as "too simple to be realistic", but we must regard them as a step beyond the old standard cosmologies, and therefore a major development in cosmological theory.

Like everyone else today, Park and Landsberg have no means of dealing directly with the computation problem of black holes. They cannot compute through the black hole/white hole transition, so they have to cheat a little: They simply reverse the collapse when the density of the model becomes too great. A model universe collapsing inward suddenly becomes, in their computer, a model blasting outward. This is one of the oversimplifications mentioned, in spite of which the intriguing results emerge.

No process is perfectly efficient — a perpetual motion machine cannot be built — and this applies, in a sense, even to a "machine" equivalent to a whole universe. You know that in pumping up a bicycle tire, the pump gets hot because of its inefficiency as a machine. If you "pump up" the Landsberg-Park oscillating universe model, the equivalent effect is that, because the universe "gets hot", each collapse phase proceeds faster than the preceding expansion. So the oscillating universe hurtles even more precipitously toward the singularity than the headlong rate at which it exploded outward from the white hole state. As we have seen, the models simply switch the universe from collapse to expansion by reversing this velocity, so every outward explosion proceeds faster than the preceding cycle. The practical result is that each cycle expands more than the one before it, pushing the

Will the "Big Crunch" Follow the Big Bang?

What proof do we have that the universe will (or won't) fall back upon itself and start all over again? The clues to look for must come from estimations of the universe's age, the rate of its expansion, the rate of its slowing down, the mass and density of its matter, and through gleaning whatever other details are available about its early conditions. That's a tall order!

We now have evidence (from the decay of longlived radioactive elements) that the universe may be as old as 20 billion years (see Astro-News, July 1977). Furthermore, we can observe the rate of expansion at which distant galaxies are moving away, and from that derive an age when they must have been all together. Measurements now place that time 16 to 20 billion years ago.

If the universe is slowing down for an eventual recollapse, the most distant galaxies we see should be going away from us proportionately faster than nearby galaxies — that is, they should have a larger Hubble constant than nearby galaxies. While the measurements are not easy, they do put a limit on how fast the universe is slowing down. The evidence somewhat favors a forever expanding universe.

We can also estimate the total mass of the universe to see if it is large enough to slow the galaxies down and start them falling back together. Again, difficult measurements suggest that it is not dense enough; hence the universe will expand forever.

Finally, the big bang left a residuum of heavy hydrogen (deuterium). By comparing observations and theoretical calculations concerning the formation of deuterium for hydrogen just after the big bang, we can deduce the early temperature and density of the universe. Again, the evidence, though a bit shaky, points to an "open", perpetually expanding universe.

In a few more decades we should have an answer we can really trust. For the time being, the evidence points toward an ever expanding universe that won't happen again!

universe ever closer to the unbound state, but never crossing the boundary.

So why should our universe be so very nearly unbound, but not quite? Simply because each cycle takes longer to complete, starting out from some infinitesimal hiccup (which may mean that we might be stuck with some kind of unique creation event after all). Early cycles were over before any life could evolve, so only a long-lived universe cycle will allow life (like us) to exist. In many ways, it's a nice picture, and one which probably points the way ahead for future development if the universe turns out to be closed after all.

Cosmologist Paul Davies has achieved the remarkable feat of overcoming the problem of the "perfect machine", explaining the origin of the cosmic microwave background radiation in one neat oscillatory model package. Instead of allowing the universe to heat up forever, he lets it heat in one cycle and cool in the next — which means that the "arrow of time" must point in opposite directions in alternate cycles. Time literally runs backwards (by our standards) in the "next" cycle! In one cycle the universe gets old, and in the next it is rejuvenated; in the next it ages again. In this picture, each pair of expansions forms the basis of spacetime. The universe is closed in space, starting and ending in a singularity; it is also closed in time, with the forward and backward halves forming a closed loop in time. Not just space, but *spacetime* is closed.

If this model had appeared in the early 1960s, the discovery of the cosmic background radiation might have been seen as evidence confirming its plausibility. Even though present fashions in universe-model building have left the Davies model in something of a backwater, there are still people who take it — well, let's say half seriously. D.T. Pegg, of James Cook University in Australia, has shown that if the two halves of the cycle are filled with antimatter and matter respectively, then time must be reversed to close the "loop" as Davies suggests. This solves another asymmetric riddle of our universe — why is it full of matter, and not antimatter? With antimatter in the other half of the universe beyond the black hole at the end of our cycle, everything looks much neater. Another theorist, M.G. Albrow (working at CERN in Geneva), likens the whole process to the situation in the microphysical world where a particle and antiparticle can be created, meet each other and annihilate.

Particle physicists are used to such situations, and are also used to describing the motion of, for example, a positron (antimatter electron) forward through time as exactly equivalent to an electron moving backward in time. Again, it seems that to close the double loop of the Davies model, we must have time flowing backward in adjacent loops, so that particles move backward in time and antiparticles flow with the arrow of time. Symmetry of space, symmetry of time, symmetry of matter and even symmetry of radiation all fall neatly out of the model. What more could the cosmologists ask?

Is this model, perhaps, too good to be true? If nothing else, its existence should prod observers to redouble their efforts to prove, once and for all, that the universe really is open and forever expanding, as the first tantalizing results suggest.

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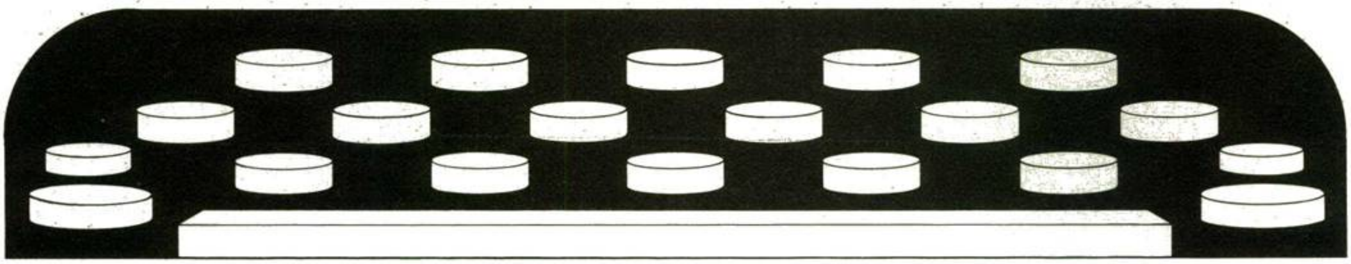
*John Gribbin was formerly the cosmology correspondent for **Nature**, and is the author of several books on astronomy. This article draws partly on material from the latest of these — **White Holes**, to be published this summer by Delacorte.*



IN FOCUS

Sir / I recently purchased a 12-1/2 inch f/5 mirror from Coulter Optical Co. I'd like to know the size of the diagonal needed and just how far to place it from the mirror.

GARY L. McMILLS
Houma, La.

Mr. McMills / The size of the Newtonian secondary is easy to calculate. For a mirror whose diameter is **m**, *with a focal length of* **f**, *where the focal point is* **b** *from the diagonal, to produce an illuminated image* **d** *in diameter, the minor axis of the diagonal should be:*

$$\text{diagonal minor axis} = \frac{b\,(m-d)}{f} + d$$

For your 12-1/2 inch f/5 telescope, the diagonal will be close to three inches minor axis. (This month's Equipment Atlas features an article which will help you finish your telescope.)

Sir / In reference to the letter from F.D. Bruner (In Focus, April 1977) regarding the visibility of Encke's division in Saturn's rings, the following information may be useful: There are many well-documented observations by reliable observers of Encke's division made with telescopes of six inches aperture, or even smaller. For example, Kater's "prediscovery" observations of it are well known; they were made with 6-1/4 inches aperture. Also, the famed W.R. Dawes (for whom Dawes' Limit is named) saw it with a 6-1/3 inch refractor. W.S. Jacob observed it at Madras Observatory with a 6.2 inch refractor — and there are many other records of its visibility with similar apertures. Remember these older refractors had no modern optical coatings to improve their image contrast either.

Closer to our own day, experienced members of the Association of Lunar and Planetary Observers (ALPO) have seen Encke's division in four inch refractors. In 1971, 1972 and 1973 I observed it with eight and six inch reflectors and even got a hint of it in my 3-1/2 inch Questar. Of course the rings must be close to or at their maximum opening, and the night must have excellent seeing for the division to be seen in smaller apertures. Once seen, however, it is unmistakable.

In my 25 years of observing the moon, planets, double stars, etc., I've found that, in general, when a book or article states that "it takes 'x' number of inches of aperture to see an object", the object can, for the most part, be seen with about half that aperture if the observer is experienced. Of course, the quoted figure is probably correct for a beginner or casual observer. Many of the "minimum aperture required" quotes have been printed and reprinted without question over and over again from old astronomy texts. It should be remembered that, while the older observers did not lack anything in skills, their telescopes (many of which were excellent optically) by today's standards are quite inefficient. Also, once an object has been discovered with a certain size instrument, people will usually find it with smaller ones. As William Herschel put it, "When an object is once discovered by a superior power, an inferior one will suffice to show it afterwards." Admiral Smythe said it even better: "Many things, deemed invisible to secondary instruments, are plain enough to one 'who knows how to see them.' "

RODGER W. GORDON
ALPO Assistant Jupiter Recorder
Nazareth, Pa.

Sir / The short article "What Are Gamma Rays?" by Gerrit L. Verschuur (ASTRONOMY, June 1977) left me somewhat baffled. The article states: "The units of energy used are measured as electron volts *of energy*. Thus, gamma rays range in *energy* from hundreds of *kilovolts* (one kilovolt is 1,000 volts) to many millions of *electron volts (megavolts)*" (emphasis added).

Unless gamma ray astronomers have changed their yardsticks, my old physics books tell me that the electron volt is a measure of energy. It is a very small bit of energy — namely, 1.6×10^{-19} watt-second. Even the energy possessed by a photon at the upper end of the spectrum (10^{20} electron volts) is only 16 watt-seconds, or the equivalent of leaving a 25 watt lightbulb on for a little more than 1/2 second.

I assume what the article intended to convey was that although this amount of energy is small in practical measure, the fact that it can be possessed by so small an entity as a photon *is* impressive. Besides, when *many* photons (billions and billions of them) have the same energy level, *then* you have lots of energy emitted from the source.

If I am correct in my assumption of the writer's intent, perhaps it would help to clarify this for other lay readers. Incidentally, *kilovolts* are *not* energy, but a measure of electromotive *force*.

WILMOT R. McCUTCHEN
Orinda, Calif.

Sir / I was intrigued by Joel McRee's report of a possible aurora visible from Bradenton, Fla. (In Focus, May 1977). However, he almost certainly saw a cloud of ionized barium gas, launched in an Honest John-Hybac rocket from Santa Rosa Island in western Florida. Eglin Air Force Base held a number of these tests early this year. The tests were designed to determine how these clouds affect communications signals sent to airplanes via satellites.

The rockets were launched shortly after sunset so that the clouds, at an altitude of more than 100 miles, would catch the sun's rays. This was at the same time that McRee saw the "aurora".

The first time I saw one of the tests, I wondered if it was an aurora — or a heck of a beautiful comet. Then I recalled that the tests were being held.

In past years, similar tests have inspired "flying saucer" sightings. This isn't surprising, because the barium cloud intially resembles a green sphere. It gradually expands (like an "approaching UFO"), develops a "tail", and disperses. Several colors, especially pink, appear.

KEAY DAVIDSON
Sanford, Fla.

Sir / On page 58 of your May issue, Joel McRee of Bradenton, Fla. reported that he saw a spectacular display in his northwest sky on Feb. 26, 1977. He thought that it was an aurora.

I saw this same display at exactly the same time in the sky to my west. It was a "barium cloud" sent up from Eglin Air Force Base, just north of Fort Walton Beach, Fla.

It was one of a series spread over several nights to determine whether a barium cloud would blanket radio commands to a satellite. I saw several other barium clouds on subsequent nights.

Eglin Air Force Base is about 313 miles northwest of Bradenton, and about 306 miles west of St. Augustine, Fla.

The latest figure that I have seen is that an aurora may perhaps be visible in Florida once every 10 years or so.

DAVID W. ROSEBRUGH
St. Augustine, Fla.

Editor's Note: The above letters are two of several received at ASTRONOMY that explain what it was that McRee actually saw. Letters were often accompanied by newspaper clippings or photographs. We'd like to thank all those who took the time to write.

Sir / In the article "Observing From the City" (ASTRONOMY, March 1977), John Harmon implies that one's eyes become more sensitive as the pupil widens over a period of five minutes or so. Actually this represents a very small factor in light adaptation and occurs in a matter of seconds. The major mechanism occurring is the replacement by the eye of visual purple, which is bleached out of the retina during periods of high light intensity.

PETER ZAREMBO
Brooklyn Park, Minn.

Sir / I would like to pass on a few thoughts based upon my experience using binoculars.

Binoculars in the low power range (6x-8x) are generally very forgiving optically, which allows for the purchase of a very inexpensive "glass" if a great deal of flexibility is available in the selection process. I have several pairs of such binoculars that were carefully selected in the $40 (and less) price range which match up extremely well with those of Leitz, Zeiss, etc. The main drawback is with the mechanical fragility of such binoculars. Generally speaking, the less expensive a pair is, the more delicately they must be handled to prevent loss of collimation or mechanical damage. If you seek a pair within this price range, be prepared to return most of those tested! However, a good one will be eventually found.

In testing binoculars, the star test is best, but if you must make a hasty decision, much can be learned during the day. An "artificial star" can generally be found if you look around. Light reflecting from a piece of metal or glass on a telephone pole is best. Also sweeping slowly across a grouping of trees with the leaf patterns filling the field will provide a sound indication as to whether an objectional degree of field curvature exists. The individual leaves allow for an excellent comparison of image sharpness at the center and edge of field, as well as the extent of "optical fall off".

I find 7x50 binoculars far superior to 7x35s for practically every astronomical condition. With practice, the 7x50s can be hand held for periods just as long and just as steadily as the 7x35s. I most often use a pair of 10x65 binoculars which I have learned to control nearly as well as smaller binoculars, and the added dividends of increased power and light grasp are obvious. Furthermore, any binocular is considerably more functional when mounted upon a tripod, and all should be adapted to allow the flexibility of being hand held or used in conjunction with a tripod when available. In my opinion, tripod mounted binoculars will reveal at least 50 percent more detail than hand held ones.

ROBERT ARIAIL
Columbia, S.C.

Sir / I noted with interest an article in Astro-News, "Apollo Asteroid Passes Unusually Close to Earth" (January 1977). However, the description of how 1976UA was discovered was not quite correct.

On the morning of Oct. 25, 1976, I looked at a plate I had taken the previous night with the Palomar 48 inch Schmidt telescope. I saw the streak almost as soon as I turned on the light box. Dr. Eleanor Helin did not have to identify the streak for me — I realized immediately that it was probably an Apollo asteroid. Later that day I told Helin about it, giving her the reasons why I thought it was an asteroid. (The ends of the trail were rounded rather than pointed like the ends of a meteor trail would have been, and the trail was more or less uniformly thick.) After viewing my plate, Helin re-examined the plates she had taken on the Palomar 18 inch Schmidt. By a rather amazing coincidence, 1976UA was found on a plate that was taken at the same time as mine.

WILLIAM L. SEBOK
California Institute of Technology
Pasadena, Calif.

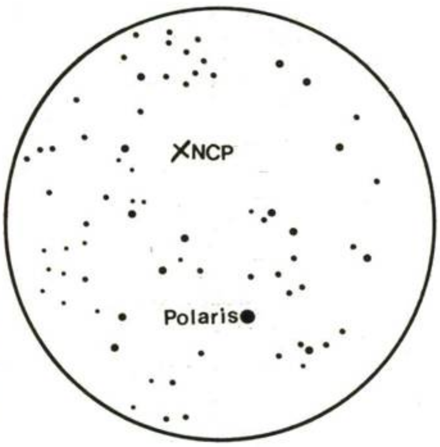
Ooops!

Here are a few errors that have appeared in recent issues:

March 1977, page 21 — the galaxy labeled "NGC-4559" is actually NGC-4569; the galaxy labeled "NGC-4569" is actually NGC-4579.

April 1977, page 44 — the period of Neptune's satellite Triton is given as "5 hours 21 minutes"; it actually is 5 days 21 hours.

June 1977, page 38 — a cross marking the exact position of the north celestial pole was inadvertently omitted in the diagram. A corrected version is given below.



The exact location of Polaris is shown in this diagram. The easiest way to find Polaris is to draw an imaginary line from the end stars of the Big Dipper. These are the lower and upper stars in the outer part of the bowl portion. Just follow this line to the first bright star you see: Polaris. For those interested in doing precise work, the inset provides a detailed map, showing the exact location of the north celestial pole.

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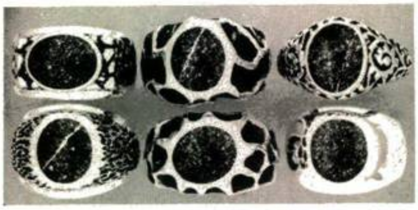

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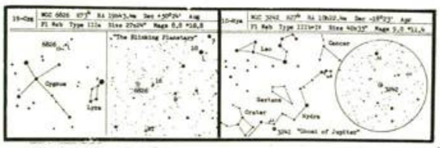

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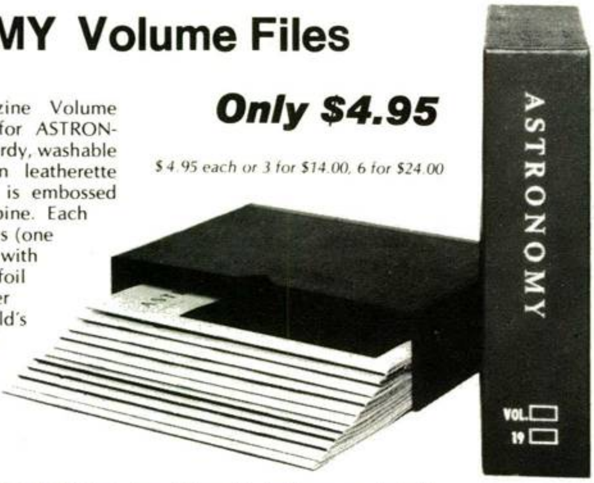

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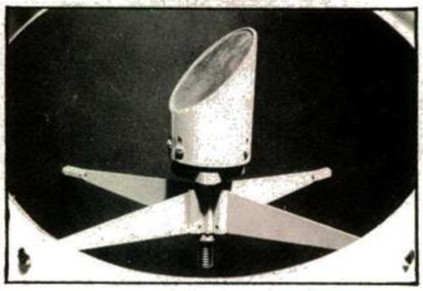

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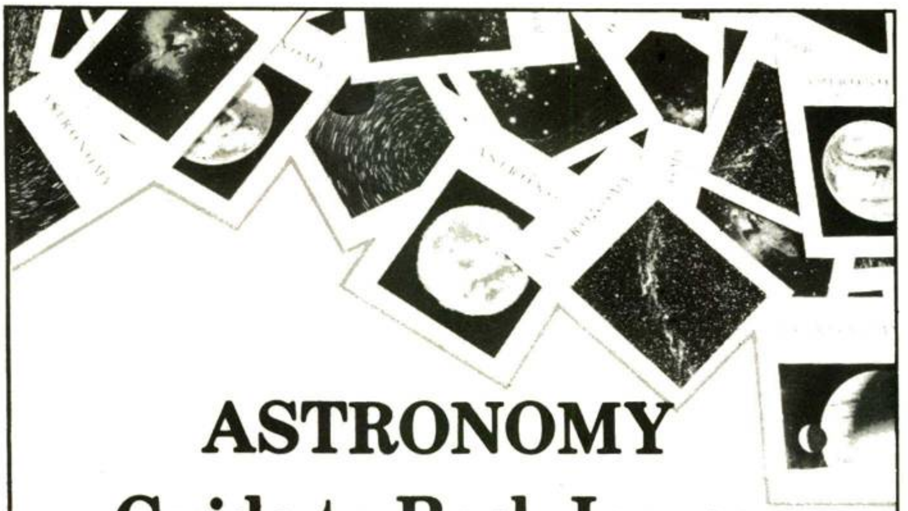

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WANTED — Chauvenet's "Spherical Astronomy" (Vol. 1, 2); Newcomb's "Compendium of Spherical Astronomy"; Oppolzer's "Canon of Eclipses"; Meeus' "Canon of Solar Eclipses"; Bell's "The Telescope"; Ball's "Treatise of spherical Astronomy". State price. Write Robert Tremblay, 1316 Teillet, Ste-Foy, Quebec, CANADA G1W 3C2.

WANTED — E. S. King's "A Manual of Celestial Photography"; Sidgwick's "Amateur Astronomer's Handbook" and "Observational Astronomy for Amateurs". State condition and price. Contact Brad Wallis, 1917 Meadow Brook Ct., Thousand Oaks, CA 91362. Phone (805) 492-2105.

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ANNOUNCEMENT — National Amateur Astronomers' Convention will be held Aug. 10-13, 1977 at University of Colorado in Boulder, with participation of AL, ALPO, IOTA, WAA. For information, write Denise Nye, NAA Convention Registration, 5604 Bowron Pl., Longmont, CO 80501.

ASTRO-NEWS

Latest News From the World of Astronomy

Scientists Propose Interstellar Clouds as Possible Sites for Life

Fred Hoyle has rekindled visions of his black cloud science fiction concept. In a recent article in **Nature**, Hoyle and N.C. Wickramasinghe of University College, Cardiff (United Kingdom) have proposed that biological organisms could be formed in the gas and dust clouds between stars. The organisms could be swept up by planets to begin new forms of life, or the cloud as a whole might even act as an advanced organism.

Astronomers know that the dark clouds in space contain microscopic graphite and silicate dust, plus over 30 molecules of varying complexity — including formic acid and methylamine which react together to form the amino acid called glycine, a component part of living systems. Hoyle and Wickramasinghe presented evidence that even more complex molecules, including the molecules of life, can be built up on the surfaces of dust grains in the clouds.

They proposed that the clumping and breaking up of dust grains in the cloud can eventually produce simple forms of living organisms, trapped and preserved inside grain clumps and feeding from the surrounding gas which acts as a nutrient. These organisms would divide and grow like any normal biological system as the grains split and recombine — except that once a grain clump is isolated from the surrounding cloud, it becomes biologically inert like a spore.

Such a spore, if it became included in a meteorite, would remain in a state of suspended animation until released in a suitable planetary atmosphere when it would spring back into life and begin to evolve in its new environment. In other words, Hoyle and Wickramasinghe proposed that Earth, and presumably many other planets, have been seeded with life which arose in outer space. This idea, a variant on the old panspermia hypothesis, would mean that life is both widespread on suitable planets and that it is biochemically similar to ourselves.

Stony meteorites such as that which landed at Murchison, Australia in 1969 have been found to contain complicated organic molecules, including amino acids, which apparently formed under the conditions in space which Hoyle and Wickramasinghe describe. But no material which is truly living has been found in meteorites. This and the failure to find life on Mars would seem to refute Hoyle and Wickramasinghe's view.

Although they do not specifically mention the black cloud concept, their arguments show that some form of exotic life might have arisen in the clouds between the stars, and that planets are not the only plausible sites for life in space. The unspoken implication must be that one cloud, somewhere, may have organized itself into an intelligent organism, so that the black cloud may not belong entirely to the realm of science fiction.

US, USSR to Cooperate on Missions

NASA and the Soviet Academy of Sciences have agreed on further cooperation in the area of manned space flight.

The agreement was signed on May 6, 1977, by Dr. Alan M. Lovelace, acting administrator of NASA, and on May 11, 1977 by Anatoly P. Aleksandrov, president of the Academy of Sciences of the Soviet Union.

The agreement is designed to provide continuity of the joint technical, scientific and operational capability developed through the highly successful Apollo/Soyuz rendezvous and docking mission conducted in July 1975. Three joint working groups will prepare recommendations for two new programs — one dealing with orbital manned flight activities and the other with a possible future international space station.

The first working group will soon begin studies on scientific and applications programs that may be conducted in joint operations of the American Space Shuttle and the Soviet Salyut space stations in the early 1980s. A second working group will simultaneously develop plans for these joint operations.

The two working groups will try to define projects which might benefit from both the flexible delivery capability and large capacity of the American Space Shuttle, and the capability for longer stays in orbit represented by the Soviet Salyut. The emphasis will be on a "science first" program which will take advantage of these capabilities and fully justify the contemplated joint operation.

It is anticipated that the studies of the Shuttle/Salyut program will be completed within 18 to 24 months, producing recommendations for consideration by both sides.

The agreement also establishes a third joint working group whose task will be to conduct a series of phased studies for an international space platform, or station. If such studies develop consensus on the objectives of future space stations, further studies will be undertaken to explore possible agreement on the conceptual design of the stations.

Neither side is committed to steps beyond the initial studies, and each reserves the right to proceed with its independent national space station interests. The agreement does, however, raise the possibility that the two sides may be able to concert their space station interests to some degree, thereby offering potential economies and efficiencies.

Kitt Peak Plans New Telescope

Kitt Peak National Observatory has released the first report prepared by a study group working on a huge "next generation telescope" for optical and infrared astronomy. The giant telescope's reflecting surface, 25 meters (about 83-1/3 feet) across, would gather several times more light than all combined telescopes presently used by professional astronomers in the United States.

"A 1,000 inch, ground based telescope," said Kitt Peak director Dr. Leo Goldberg, "would open up an entire new era in astronomy and provide information critical to a broad range of fundamental questions." Since 1960, two national committees on astronomy have emphasized the need for such new large ground based telescopes. Astronomers believe such a telescope is needed to complement observations with the new Very Large Array (VLA) radio telescope and NASA's planned Space Telescope. The three together would provide the capability of extending the frontiers of observational astronomy for the coming decades.

The report released by Kitt Peak outlines some of the areas of observational astronomy which the proposed giant telescope is expected to revolutionize. The 25 meter aperture would be large enough to permit detailed spectrographic research on winds and "weather" on other planets in our solar system. The tremendous light gathering power of such an instrument would also allow highly accurate diameter measurements of the far off planet Pluto. Many of the asteroids, moons of the other planets and even comet nuclei would also become measurable.

The same observational techniques might also permit direct detection of faint companions — stellar bodies or even planets such as Earth — suspected to orbit other stars in our galaxy. The proposed telescope would be powerful enough to allow magnetic field and limb-darkening studies of far off stars. Detailed observations of extragalactic objects such as mysterious quasars could also be made.

The largest existing optical telescopes — the Russian six meter located on Mount Semirodnika in the Caucasus Mountains and the U.S. five meter (200 inch) on Palomar mountain in southern California — represent the largest telescopes which can be built to conventional designs at acceptable cost. In order to make the jump to the 25 meter aperture, the Kitt Peak group is investigating four separate concepts which entail entirely new approaches. These include a rotating shoe shaped structure paved with mirrors, a steerable dish surfaced with mirrors, a set of small telescopes on a single large steerable frame, and an array of individual telescopes arranged so that their optical beams can be combined. According to Goldberg, reports on these studies are being circulated and reviewed on a worldwide basis, and it is likely that other approaches will be proposed for review by the group.

"The preferred concept," said Dr. Donald N.B. Hall, project scientist, "will be the one that emerges as the most cost effective design." New lightweight mirror and telescope mounting materials will be tested, and positional control systems utilizing computers and laser systems will be investigated by the Kitt Peak group. "The scale of this telescope," said one engineer, "makes most conventional telescope designs obsolete or inadequate. New approaches are mandatory."

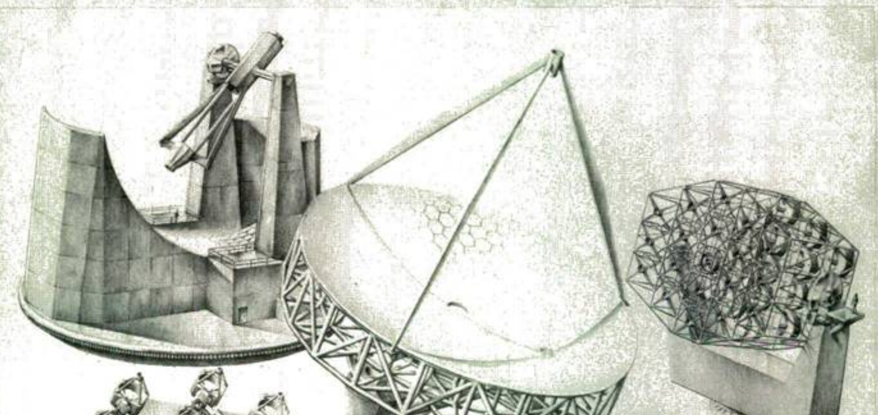
All the designs being considered require the combining of the light from hundreds of mirrors (each one to two meters across) to duplicate the performance of a single 25 meter mirror — a factor leading to huge savings in weight and cost. These mirrors will have to be mass produced using recently developed techniques rather than time-consuming hand polishing. During observations, all the mirror elements will be positioned by a computer which will use lasers to sense their individual positions.

Computers are expected to play a major role in the design concepts for the large telescope. "We expect computers to control shape of the primary mirror, the optical spacing between the primary and secondary, the pointing attitude of the telescope, and the data taking instrumentation," said L.D. Barr, project engineer. "In addition," he said, "computers may do special things, such as damp out structural vibrations by controlling the sequence of actuations used to control mirror segments."

The Kitt Peak group also plans to use computer simulations for detailed comparisons and evaluations of the different designs and proposed materials. According to project engineers, the computer simulations will also give insight as to how each of the designs might function in actual use.

A project such as this study is a natural outgrowth of Kitt Peak's role as the national center for optical astronomy, and preliminary research has been in progress for nearly two years. The studies were initiated by Hall, who remains as project scientist, and are managed by Barr, the project engineer. The study group, which includes scientists, engineers and optical experts, will issue a number of reports describing the various approaches over the remainder of 1977. After one approach is chosen by the U.S. astronomical community, more detailed engineering of the actual telescope will begin.

At that time, measurements to establish the most favorable site for such a 25 meter telescope would also begin. A number of sites within the continental U.S. (including several in the Tucson, Ariz. area) and Hawaii are under consideration.



Kitt Peak National Observatories Photograph

Telescope Studies Southern Regions

Until recently, serious study of the sky's south polar region has been limited. Major observatories were all located at latitudes where the southern stars never rose, with the result that many fascinating objects in the southern sky — including the southern Milky Way, the Magellanic Clouds, and bright clusters and nebulae — have been almost completely neglected. Observatories in South America and Australia have enabled astronomers to make serious observations on a scale and intensity previously thought impossible, and scientists have welcomed the chance to do so. A new opportunity has been provided with the opening last year of the Hale Observatories' 100 inch Irénée du Pont telescope at the Las Campanas Observatory in Chile.

Las Campanas — a mountain ridge about three miles long, with peaks ranging from 7,500 to 8,300 feet in height — was chosen in 1968 as the site for the new observatory by the Carnegie Institution of Washington, D.C., co-operator (with the California Institute of Technology) of the Hale Observatories. Las Campanas' superb seeing conditions (perhaps the best in the world) provided the final impetus for the choice. The Las Campanas Observatory already houses a 40 inch reflector, a 10 inch photographic refractor, and a 24 inch reflector operated by the University of Toronto.

The optical design of the Irénée du Pont telescope was developed by Dr. Arthur H. Vaughan, assistant director of Las Campanas Observatory, and the late Dr. Ira Bowen, former director of the Hale Observatories. A Ritchey-Chrétien optical system is among the telescope's features. Designed by Bowen to provide a wide field for photography, the system gives sharp focus on objects all the way to the edge of the 2.1 degree field. A radically new coudé optical system, providing maximum efficiency for observations of the south polar region, is also included in the new telescope. A microcomputer system sets the telescope to desired positions, provides variable tracking rates, automatically moves the dome and windscreen, and assists the observer with data acquisition.

Automated controls and sensing devices permit remote observing, and a closed circuit television system permits acquisition and guiding on extremely faint objects. The telescope is designed for use with various auxiliary instruments, including devices for spectroscopy, photometry and infrared observations.

In addition, the dome's observing floor is equipped with a chilling system that will improve optical performance by minimizing air turbulence. Vacuum equipment, used for coating the surface of the main mirror and its auxiliary mirrors with highly reflective aluminum, is kept on the ground floor.

The primary mirror of the Irénée du Pont telescope is a solid disk of fused silica 101 inches (256cm) in diameter, and 15 inches (38cm) thick. It was cast by the Corning (N.Y.) Glass Works, and ground, polished and figured at the University of Arizona's Optical Sciences Center, under the supervision of the Hale Observatories. The total weight of the telescope's moving parts (including the mirror) is 67 tons.

A specific fraction of observing time at Las Campanas is reserved for Chilean astronomers who present meritorious research proposals. Since 1970, the Carnegie Institution has awarded predoctoral fellowships, assisting qualified Chilean students to obtain the Ph.D degree. The Chilean government has encouraged and aided the observatory's development, as well as that of other observatories nearby, including the Cerro Tololo Inter-American Observatory. In fact, the Las Campanas region of Chile holds the largest grouping of major astronomical equipment in operation anywhere in the world.

In the period following the Oct. 6 dedication, the telescope will undergo several months of testing — including many tests of photographic equipment — before any research programs will be accepted. Auxiliary instruments must also be tested, and it will most likely be several months before the instrument goes into full time operation.

Guests at the dedication ceremony included Mr. and Mrs. Crawford H. Greenewalt, who provided the major funding for the new instrument, and Dr. Henrietta Swope, a long time Carnegie researcher whose gift made the development of the Las Campanas site possible. Unfortunately, the dedication night was marred by overcast skies.

BRIEFS

● NASA's Marshall Space Flight Center has awarded a one year, $150,000 contract to the Illinois Institute of Technology Research Institute to establish a manufacturing applications team. The new team will review NASA developed technology and identify techniques or processes that may be of use in solving problems unique to the manufacturing industry.

● NASA aeronautical engineers are conducting intensive research on the problems of spins and stalls in light, general aviation airplanes. The NASA Research and Technology Advisory Council Panel on General Aviation Technology sees stalls and spins as the most important safety problems facing light plane designers, since they account for 30 percent of all fatalities in light planes.

● Two satellites that were designed to live 18 months — Velas 9 and 10 — will celebrate their eighth year of continuous operation this month.

Launched into a 60,000 nautical mile circular orbit, the TRW-built satellites were designed to record nuclear events from sea level to deep space, and monitor any nuclear test ban violations. The satellites also observe solar radiation. Data collected from the Vela satellites were used to predict solar flares during the Apollo missions.

● An array of solar cells that convert sunlight into electricity was recently installed to store power in batteries operating a highway sign near Casa Grande, Ariz., as part of a joint experiment by the Arizona Department of Transportation and two federal agencies. Forty duststorm warning signs are being installed on routes 10 and 8 to demonstrate the practicality and benefits of solar cell energy.

● Earth orbiting satellites, such as NASA's Landsat Earth resources satellite and the National Oceanic and Atmospheric Administration's meteorological satellites, are currently being tested in the seasonal prediction of water supplies from snow in California's drought-stricken Sierra Nevada and other western mountains.

The "big picture" capabilities provided by satellite are less expensive and faster than conventional aerial surveys. Satellites also allow the same snow cover area to be mapped repeatedly under a relatively constant viewing perspective.

NASA — Developed Bubble Suit Frees Isolated Immune Deficient Children

Children born without immunity to germs have led lives of limited mobility in closed rooms until recently. Now, thanks to a spinoff from the space program, these children will have a chance to venture forth into the world outside their hospital rooms.

This inherited disease, Severe Combined Immune Deficiency, strikes one in every 10,000 males. The patient has absolutely no defenses against germs; even the simplest germ can be fatal. Shortly after birth, the infant is whisked into an isolated plastic crib where the environment is completely sterile. The patient can live at home if it can be equipped with a sterile room, and a plastic bubble must be used for transportation to and from the hospital.

Greater mobility for the patient is offered in a spacesuitlike garment called the Mobile Biological Isolation System. Originally the suit was designed as part of the Apollo quarantine program; astronauts returning from the moon wore the suits during crew recovery operations to prevent the spread of "lunar germs". Although the suit was originally designed to keep germs in, it can also be used to keep germs out; this is where the practical applications come in.

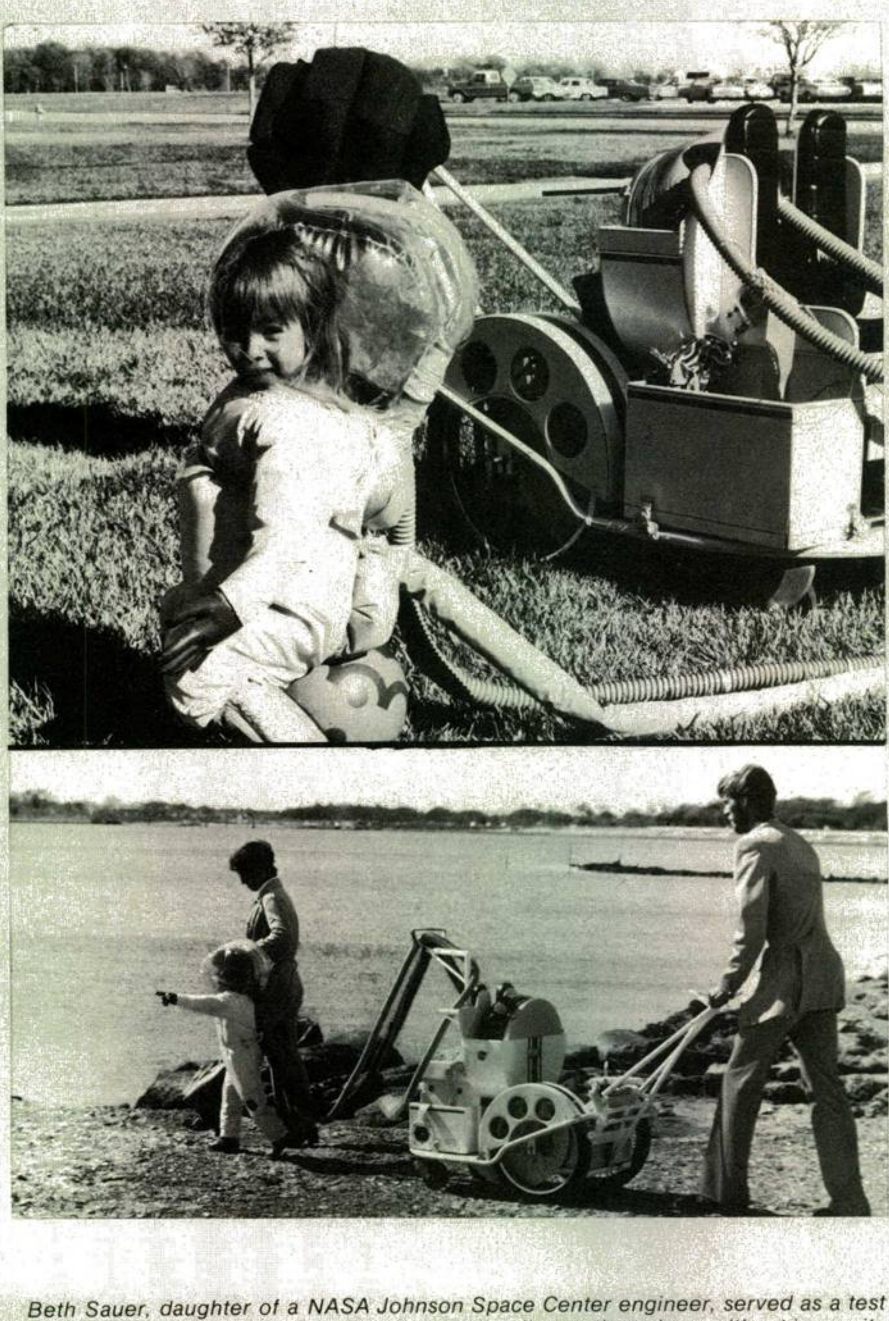
Scientists at Johnson Space Center designed and fabricated the suit as part of a cooperative program with the Baylor College of Medicine, where it was tested. Using commercially available components where possible, the engineering team used a design approach similar to the one used in the Apollo program.

The garment is made from a rubberized fabric similar to that used in life rafts, and is fitted with a helmet of soft, transparent plastic. A foldup tunnel attached to the back of the suit permits the patient to move from his sterile room into the suit without exposure to the outside atmosphere. The garment allows patients to carry a germ free environment around with them for periods up to four hours.

A modified lawnmower chassis serves as a carrier for the air blowers and batteries, and has a seat for the patient. Two fans force air through a high efficiency filter pack, through the 10 foot air supply hose, and into the suit. Rechargeable 12 volt aircraft batteries provide power to the fans, or the system can be connected to 100 volt AC house current or driven by an automobile battery through the cigarette lighter. Airflow entering the suit passes inside the top of the helmet and over the body for cooling, and exits at the ankles.

Potential uses of the isolation garment are not limited to immunity-deficient children; patients with aplastic anemia or those who are undergoing chemotherapy or organ transplant could likewise be freed from their sterile plastic room for short periods.

Project engineer Fred Spross of the JSC Bioengineering Systems Division says the suit and pushcart could be mass produced commercially. "The technology for the garment was already available from our space experience," said Spross. "We didn't have to go into a lot of new development work." Spross and his colleagues are hopeful that a manufacturer will take up the isolation garment project and market them for child and adult patients who want to see the outside world.



Beth Sauer, daughter of a NASA Johnson Space Center engineer, served as a test subject for a spacesuitlike garment which may allow patients born without immunity to germs to venture out of their sterile environments. NASA photographs.

Solar Holes Alter Magnetic Field

Coronal holes, openings, in the sun's hot atmosphere are the source of significant variations in Earth's magnetic field, according to a paper recently published by Dr. Neil Sheeley of the Naval Research Laboratory, Jack W. Harvey of Kitt Peak National Observatory, and William C. Feldman of Los Alamos Scientific Laboratory.

According to the three scientists, coronal holes seem to be a source for the high velocity solar wind. The sun rotates, and as a result, coronal holes transit the disk of the sun.

"Measurements made during our three year study period," said Sheeley, "showed that the solar wind doubled its speed past Earth nearly every time a coronal hole moved across the sun's disk." When this high speed solar wind sweeps by Earth, it produces fluctuations in our planet's magnetic field.

For centuries, scientists have observed short-lived geomagnetic disturbances, characterized by changes in the strength and direction of Earth's magnetic field. Because such changes tend to recur every 27 days — a timespan matching the sun's rotation period as seen from Earth — they were assumed to have a solar origin. But no obvious source feature could be found on the sun, and this mysterious nature of the unseen solar sources earned them the name "M-regions".

The recently completed joint study spans three years — 1973 to 1976 — and provides conclusive evidence that coronal holes, high speed solar wind streams, and magnetic "storms" on Earth are related. Sheeley, Harvey and Feldman used data from both manned and unmanned spacecraft and from a ground based telescope in compiling their information.

Coronal holes are solar regions where the density and temperature of the corona are lower than average, and where the lines of force of the sun's magnetic field open outward, allowing material to escape from the sun more easily. This fast outflow of solar material interacts with Earth's magnetic field. "It is this interaction," said Harvey, "which literally *jiggles* our planet's magnetic field."

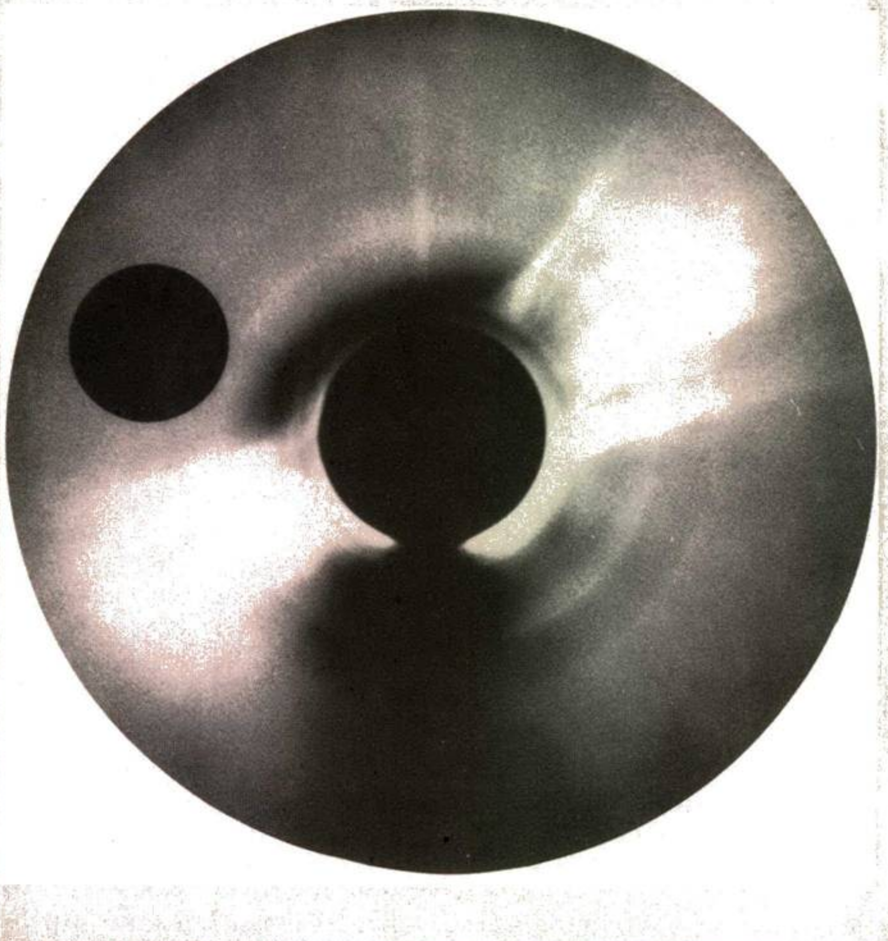
The first clue to the true identity of the mysterious solar M-regions came from comparison of a few isolated rocket observations of coronal holes with spacecraft observations of the solar wind. Although such comparisons were encouraging, they were too few in number to be entirely convincing.

It was not until the Orbiting Solar Observatory (OSO) 7 satellite and the Skylab-Apollo Telescope Mount missions during 1972-73 that extensive periods of coronal hole observations became available for comparison with solar wind observations. About the same time time, a new instrument began taking shape at Kitt Peak National Observatory. Built partly in support of the Skylab mission, the Solar Vacuum Telescope was capable of observing coronal holes from the ground.

In their study, Sheeley, Harvey and Feldman combined coronal hole observations made at Kitt Peak from 1974 to 1976 with similar observations from the OSO-7 and Skylab satellites. In this way, it was possible to compare observations of coronal holes, the solar wind, and geomagnetic disturbances over an extended period of time. The result leaves little doubt that coronal holes are the mysterious, long-sought solar M-regions.

By observing coronal holes on a daily basis with ground based telescopes, the scientists say that fairly reliable predictions can be made concerning forthcoming magnetic "storms" on Earth. Using the Solar Vacuum telescope at Kitt Peak, Sheeley and Harvey have been able to forecast geomagnetic disturbances about a week in advance — the time that it takes a coronal hole to move across the face of the solar disk from its eastern edge to the center, plus the 2-1/2 day sun-to-Earth travel time for the expelled material.

Advance warning of such magnetic disturbances may help mapmakers, explorers searching for mineral deposits, and medical researchers. Others using magnetometers — climatologists studying the relationship of solar activity to Earth's weather, seismologists attempting to gather forecasting data on earthquakes, and geologists studying continental drift and plate tectonics — may find the discovery useful.



Solar flares extend outward creating coronal holes in this coronagraph taken during the Skylab mission. Extensive studies of coronal hole activity were made using Skylab's Apollo Telescope Mount during 1972-73. The dark circle to the left is the moon. Coronagraph courtesy of NASA/Skylab/High Altitude Observatory.

ASTRONOMY

Index to Volume 4, 1976

ASTRONOMY's cumulative Index to Volme 4, 1976 is now available. This subject index covers the months of January through December 1976 (issue Nos. 1 through 12) in an expanded format, making it a valuable addition to your home library!

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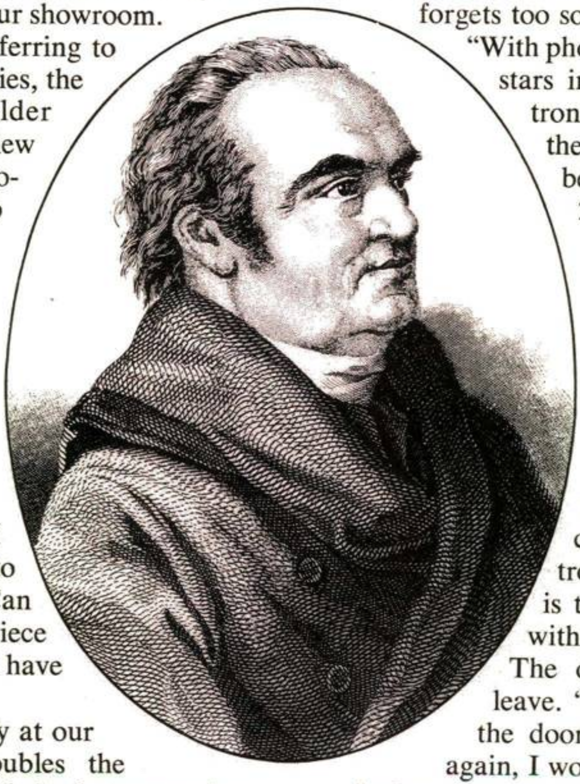
"If I'd had all these Unitron accessories," William Herschel told us, "I would have discovered twice as much."

Herschel discovered quite a bit, actually, including the planet Uranus, and advanced the science of astronomy with the telescopes he built himself. But even though he polished the 48-inch mirror for his great 40-foot reflector, he was absolutely captivated by the Unitron accessories he saw in our showroom.



"If I'd had this," he said, referring to one of our most useful accessories, the Duetron double eyepiece holder which allows two observers to view simultaneously, "my sister Caroline would have been able to assist me even more with my observations."

Another device that caught Herschel's eye was the Unihex rotary eyepiece selector — exclusive with Unitron— which lets you change from one to another of six eyepieces instantly and without fumbling. "You know," he chuckled, "I had to climb a 50-foot ladder to peer into my large telescope. Can you imagine dropping an eyepiece from that height? What I would have given for your Unihex!"

Herschel grunted approvingly at our achromatic amplifier that doubles the power of any eyepiece used with it, then paused at our sun projection screens with Uniclamps. "I would have liked to have done more sun observations," he mused, "and with this, I could have." We showed him how its white screen receives the sun's image for safe viewing.

The great astronomer was particularly intrigued by Unitron's accessories for photography. "The eye forgets too soon what it sees," he remarked. "With photographs I could have observed stars in the daytime. You know, astronomy is a splendid vocation, but the hours are terrible." He liked best the Unitron Astrocamera 220 with its ground-glass focusing back and air-operated shutter (no vibrations) with speeds from 1/90 sec to 1/10 sec, bulb and time.

"Would I have to use a Unitron telescope to enjoy all these fine accessories?" he asked. We assured Herschel that nearly any good telescope could be improved with Unitron accessories, but the best way is to start with Unitron and stay with Unitron.

The old astronomer got ready to leave. "I assure you," he called from the door, "if I had it to do all over again, I would have used a Unitron."

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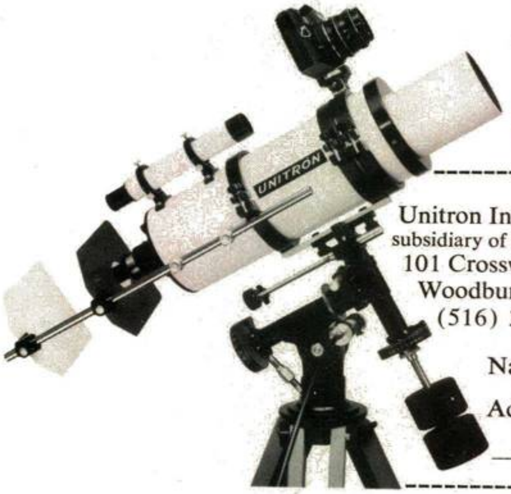

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PUBLISHER'S MEMO

In case you hadn't noticed, it's August (my-oh-my how time flies when you're having fun!!!!). Anyway, this is the August Publisher's Memo — just in case you got this issue of ASTRONOMY in late July (we hope!) . . . .

Which leads me to philosophize for a moment. There is but one thing in life upon which we may assuredly depend: Regardless of wind or hail or dark of night, the U.S. Slowstal system shall keep its appointed rounds — very unpredictably!!

Sweltering forward, this issue of ASTRONOMY starts our fifth year of continuous and uninterrupted monthly publication! It is indeed sobering to me and delightfully gratifying to all we Astro-people that ASTRONOMY magazine is filling a definite need and continues to proliferate even in the face of a frighteningly gloomy magazine mortality rate.

You see, my friends, out of 30 newly started magazines, only one will survive beyond its first year of publication. But ASTRONOMY has already survived four years, and we've got some fantastic (we think) ideas for the next four.

By now you should have received our special **Inflation Fighter** mailing notifying you that ASTRONOMY's subscription price will rise to $15.00 a year *next* August (1978), so we can abate the swift tide of inflation. You can thank AstroMedia Corp.'s new president, Bob Maas (I've nicknamed him "Mighty Maas"), for projecting the expense increases ASTRONOMY will incur far enough into the future, to allow us to give you more than a year's prior notice.

As early as mid-1975 I could see inflationary "writing on the wall" and, in my July 1975 Publisher's Memo, I went into some detail on the monumental expense increases we had already incurred up to that point in time — only two years after we started publishing ASTRONOMY.

To our many new "Friend of an Inflation Fighter" subscribers, welcome aboard! Since you may not have been exposed to my Publisher's Memos as have your friends, this department spans a gamut from serious and businesslike to silly, giddy, and even downright irreverent. It's where we, at ASTRONOMY, let it all hang out. You see, a highly tuned, technical, scientifically oriented editorial staff like ASTRONOMY's (including me) may tend toward the stuffy and hidebound — at times taking ourselves too seriously. So my Publisher's Memo provides us a continuing source of humility therapy as I deliciously report to you our less than dignified antics and pratfalls while helping build an *esprit de corps* and rapport which extends to and includes all of ASTRONOMY's subscribers and readers.

When my Publisher's Memo has to report something of a more serious nature, I straighten up the tone long enough to tell you what must be said without mincing words. You — the subscriber, and the guy/gal who pays the bills — are king here at ASTRONOMY. Therefore, we believe you have the right and we an obligation to keep you informed and up-to-date on any matter that might affect you.

Moving along in that vein, this month ASTRONOMY is conducting the largest direct mail subscription building campaign we have ever done. I'll keep you posted on its progress.

In closing, we hope you like our new set of cosmic art reprints. Please let us know what other subjects you would like to see enlarged for our second series later this year or early in 1978.

As if I haven't said enough . . . gasp . . . gasp . . . till next "moonth" . . . .

Sincerely,

Stephen A. Walther

Stephen A. Walther
Publisher

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Las Vegas, NV 89104
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Reno, NV 89557

NEW JERSEY

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Dover, NJ 07801

Edmund Scientific
101 E. Gloucester Pike
Barrington, NJ 08007

Ridgewood Camera
48 E. Ridgewood Ave.
Ridgewood, NJ 07450

Tuthill, Roger
11 Tanglewood Lane
Mountainside, NJ 07092

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Lake View Dr.
Tomkins Cove, NY 10986

Johnson's Studio & Camera
3208 Erie Blvd.
De Witt, NY 13214

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66 Franklin St.
Rochester, NY 14604

Stangert Corp.
94 Long Beach Rd.
Island Park, L.I., NY 11558

Vernonscope
5 Ithaca Rd.
Candor, NY 13743

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Parma, OH 44129

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Burke Baker Planetarium
5800 Carolyn St.
Hermann Park
Houston, TX 77004

Keaton Kolor
3520 N. 6th St.
Abilene, TX 79603

Pampa Photo
1820 N. Hobart
Pampa, TX 79065

Studer's Photo
146 Stribling
San Antonio, TX 78292

Texas Camera
5307 Airport Blvd.
Austin, TX 78765

Texas Nautical
3209 Milam St.
Houston, TX 77006

Total Camera
6128 Westheimer
Houston, TX 77057

UTAH

Allen's Camera
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Provo, UT 84601

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Salt Lake City, UT 84111

WASHINGTON

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Tacoma, WA 98402

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Seattle, WA 98101

B. E. Meyers & Co.
2717 200th Ave. S.E.
Issaquah, WA 98027

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Milwaukee, WI 53208

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Place Bell, Ottawa
Ontario, Canada K2P 2C4

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186 Queen St. West
Toronto, Ontario
Canada M5V1Z1

Lewis Instruments LTD.
1438 Erin St.
Winnipeg, Manitoba
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Vancouver, B.C. Canada V6J 3J9

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NEW DEALER INQUIRIES INVITED

STAR DOME

AUGUST

by
James Mullaney and Henry J. Phillips

Crossing the meridian on August evenings is one of the most familiar of all star groupings: the summer triangle, made up of the three first magnitude stars Vega, Deneb and Altair. The figure is actually visible during half of the year (from late May through mid-November), but is seen to best advantage during the hot and sultry nights (or cool and comfortable, depending on your location) of late August. The triangle enframes the Cygnus starcloud, one of the richest portions of the Milky Way. Sweep along this densely star-packed region of the sky with binoculars or an RFT; you won't regret it!

Although classed as first magnitude stars, the three components of the triangle differ noticeably in brightness. Vega, in the constellation Lyra, is the leader of this trio with a magnitude of exactly 0.00. Fifth brightest of all stars, Vega's prominence in our skies is partly due to its nearness: It is only about 26 light-years away. Vega is a blue-white star of spectral class A0 — very similar to Sirius, the brightest star in the heavens.

Less bright than Vega but even closer to Earth is Altair in the constellation Aquila. Altair is only 16 light-years away and shines at magnitude 0.77. It is a white star of spectral class A7. Both Vega and Altair are everyday, run-of-the-mill main sequence stars like our sun, and are expected to follow the normal evolutionary path of such stars over the next few billion years.

The third member of the triangle is also of spectral class A (more precisely, A2), but could hardly be more different from Vega or Altair in most other respects. Deneb, in the constellation Cygnus, has a magnitude of 1.26. But unlike Vega and Altair, whose nearness is partly responsible for their brightness, Deneb is bright in spite of its distance — an incredible 1,500 light-years away! The light we see coming from Deneb tonight left the star at the time of the fall of the Roman Empire.

Deneb must be intrinsically very luminous to be so bright at such a distance — and so it is. Deneb is one of the most luminous supergiant stars in the sky, with an *absolute magnitude* of -7.1. (A star's absolute magnitude is the magnitude it would appear to have if it lay at a distance from Earth of 10 parsecs, or 32 light-years.) If Deneb were as close as Vega or Altair, it would be about 20 times brighter than Venus at its best, far overpowering the comparatively feeble light of its two triangle companions. Conversely, if Vega and Altair were as distant as Deneb, we couldn't see them at all from Earth.

Vega, Deneb and Altair are the leading lights of their respective constellations. In former times, Lyra, Cygnus and Aquila all represented birds; today, Cygnus is still a swan and Aquila an eagle, but Lyra has been changed from its former designation as a vulture into a musical instrument — the lyre, a type of small harp. In fact, the Greeks knew Lyra as such, and it was the Arabs who transformed it into the vulture — or, according to some authorities, a swooping eagle (in contrast to Aquila, the flying eagle).

None of the other stars in Lyra has a magnitude greater than 3.25, but the constellation's pattern is distinct: a triangle (including Vega) attached to one corner of a parallelogram. One of the stars in the latter figure is the eclipsing binary Beta Lyrae, while Epsilon Lyrae, the famous "double double", is in the triangle.

Aquila's chief claim to a notable star configuration is the row of three stars formed by Altair and its two fainter companions, one on either side. The trio looks like a less glorified version of Orion's belt and, like it, is situated nearly on the celestial equator.

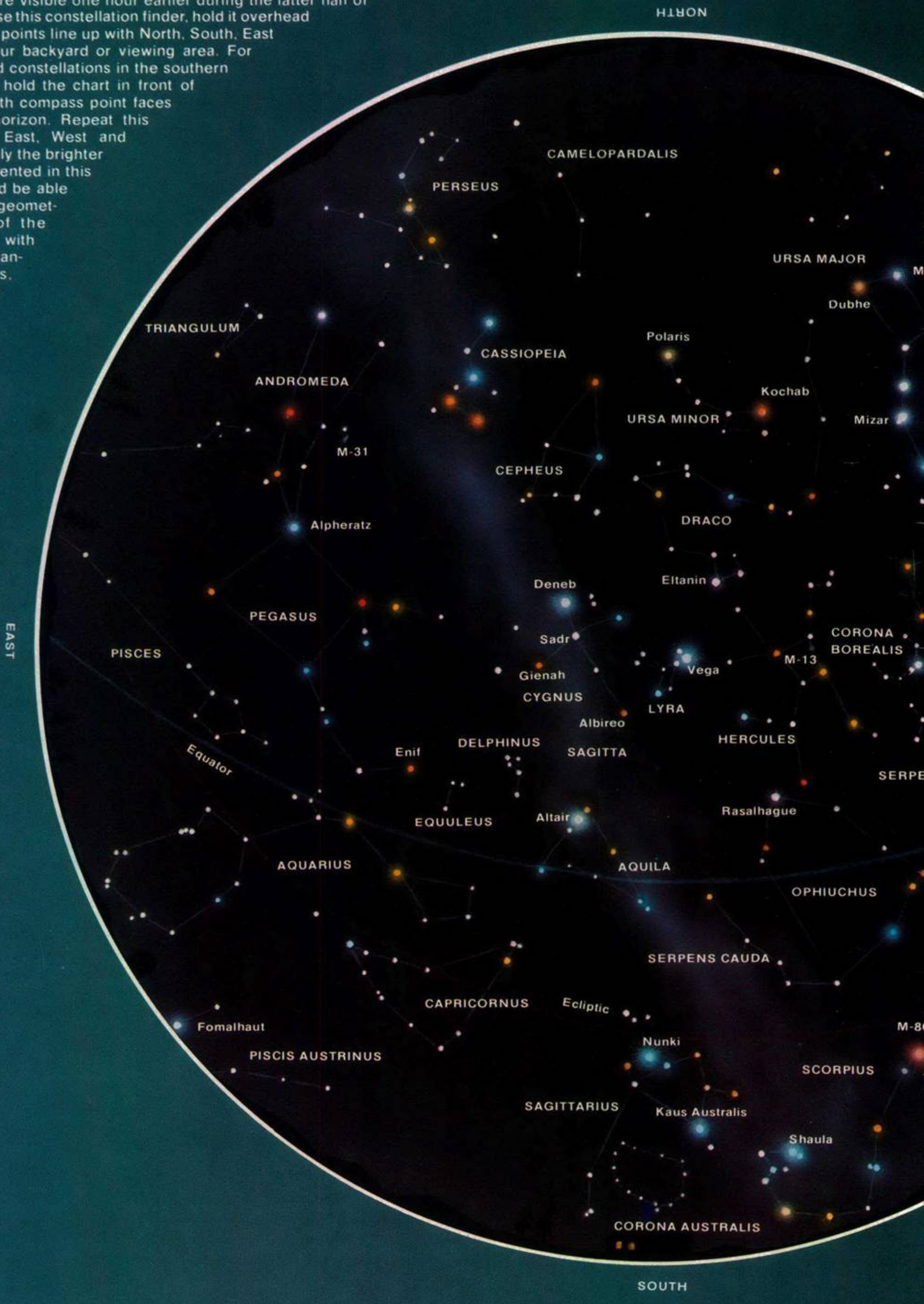
The stars of Cygnus form the magnificent Northern Cross, which is much larger and more crosslike in shape than its famous southern namesake. The star at the center of the crosspiece, Gamma Cygni, is named Sadr; long exposure photographs reveal vast areas of nebulosity filtering through the Milky Way around this star. At the foot of the cross is the unforgettable double star Albireo, one of the most beautiful color contrasting doubles in the sky and a favorite telescopic showpiece.

Between and near these three great constellations of the late summer are four smaller ones: Vulpecula the fox, Sagitta the arrow, Delphinus the dolphin, and Equuleus the colt. We generally think of the smaller constellations — those that are the mortar between the bricks of the large groups, as it were — as fairly recent inventions, not handed down from the ancients. In this case, however, three of these tiny groups have been around since at least the Greek era, and Vulpecula — the one that *was* concocted in the 17th century — is the largest in area of the four! In fact, Equuleus and Sagitta are the second and third smallest of all our 88 constellations; only Crux (the Southern Cross) is littler.

Of these four groups, Delphinus is perhaps the most distinctive; its stars form a tiny diamond, with a fifth star hanging tail-like from its tip. Its two brightest stars are named Sualocin and Rotanev — titles which, when spelled out backwards, form the name of a 19th century Italian astronomer.

In light of recent discussions of the dolphin's great brain power, it's worth noting that this animal has always had

This Star Dome rendering approximates the sky as it appears at about 11:30 p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page **36**.


NORTH
CAMELOPARDALIS
PERSEUS
URSA MAJOR
Dubhe
TRIANGULUM
Polaris
CASSIOPEIA
ANDROMEDA
Kochab
URSA MINOR
Mizar
M-31
CEPHEUS
DRACO
Alpheratz
Deneb
Eltanin
PEGASUS
CORONA
BOREALIS
EAST
Sadr
PISCES
M-13
Vega
Gienah
CYGNUS
LYRA
Albireo
HERCULES
Enif
DELPHINUS
SAGITTA
Equator
SERPE
Rasalhague
EQUULEUS
Altair
AQUILA
AQUARIUS
OPHIUCHUS
SERPENS CAUDA
CAPRICORNUS
Ecliptic
M-8
Fomalhaut
Nunki
PISCIS AUSTRINUS
SCORPIUS
SAGITTARIUS
Kaus Australis
Shaula
CORONA AUSTRALIS
SOUTH

Map Centered on 43° North Latitude

ak
CANES VENATICI
Cor Caroli
COMA BERENICES
BOOTES
Arcturus
lphecca
WEST
S CAPUT
VIRGO
LIBRA
tares

Map by Adolf Schaller

a reputation as one of Earth's more intelligent creatures. The Greek poet Arion (who attained a semimythical status) was supposed to have been rescued from his pirate abductors by a herd of dolphins who responded to his songs, and on whose backs he rode to freedom.

In an interesting reversal of this story, the young wine god Dionysus was once captured by a band of seagoing brigands. Believing that the god was a prince, they thought they might be able to extort ransom from his family. Instead, Dionysus caused their boat to be stuck fast in the waters of the Mediterranean Sea; grape vines grew madly up its masts, the decks ran with wine, and the sounds of fevered, ecstatic singing could be heard — but no one could be seen. Finally the terrified pirates leaped into the sea, where they were changed into dolphins.

Arabian astronomers also thought highly of the dolphin; one description called it "a marine animal friendly to man, attendant upon ships to save the drowning sailors". But Delphinus has not been a dolphin everywhere. In New Zealand, the constellation Aquila was an ogress, and Delphinus was the man who had killed her. It is also sometimes called "Job's Coffin", for unknown reasons.

Sagitta the arrow, not far from Delphinus and usually considered a sort of companion to that group, is called an arrow in every known ancient reference. Its stars really resemble an arrow, with Gamma and Delta Sagittae forming the shaft, and Alpha and Beta Sagittae the tufted feathers at its base. Perhaps it's a poorly aimed shot from Aquila's southern neighbor, Sagittarius the archer!

Even tinier than these two is Equuleus the colt, first mentioned by Ptolemy in the second century A.D. It might have been meant to serve as a companion to (or child of) its huge neighbor Pegasus, the winged horse. Equuleus' brightest star, Alpha, is named Kitalpha, from the Arabian name for this constellation. The reasons for its formation remain obscure, for Equuleus, unlike Delphinus and Sagitta, does not have a small, compact stellar pattern — merely a very little area of the sky with a sprinkling of stars. Take a few moments from your Milky Way sweeping to inspect Equuleus; it and its tiny neighbors possess a unique charm.

Close-Up

Vulpecula/Sagitta/Delphinus/ Equuleus Region

August's region of four adjoining heavenly precincts is a binocular and RFT user's paradise. This area is so rich in low power, wide field wonders, that we could easily devote all of our Close-Up section to these sights, forsaking telescopic objects altogether!

A rich section of the summer Milky Way passes diagonally through the northwestern ramparts of this region, but the galaxy noticeably thins out to the southeast. Sweeping from Vulpecula through Sagitta and Delphinus to Equuleus provides a dramatic demonstration of the changes in stellar density as we move away from the plane of our galaxy.

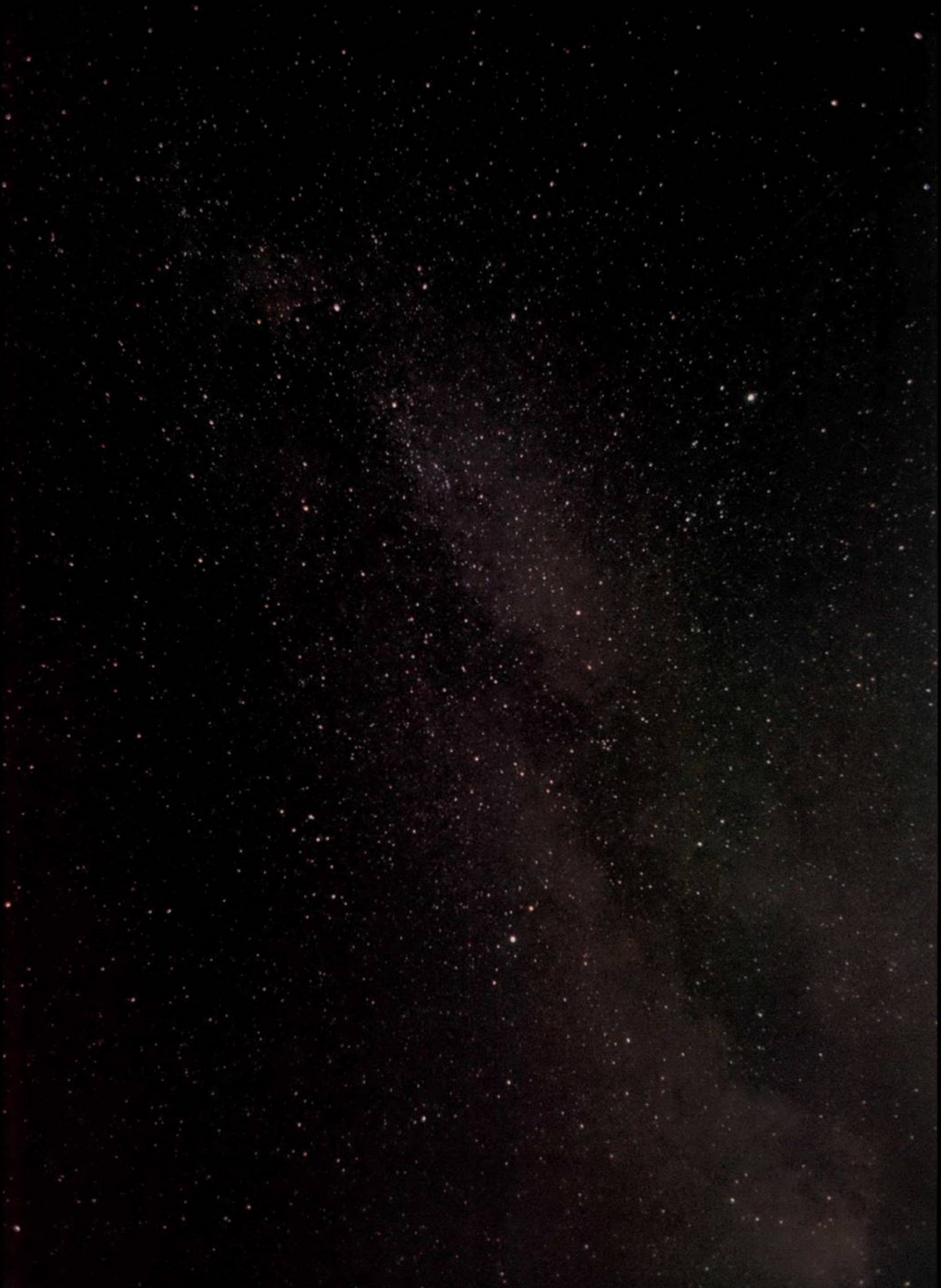
Webb, referring to the star fields of Vulpecula and Sagitta, remarked "grand sweeping", and "sweeping here magnificent". Barns described Delphinus as a "dainty asterism . . . for all its limitation in size, will be found quite a varied treasury", and the "tiny asterism" of Equuleus a "limited depository of stellar curios" but still a "lively region for random sweeping". Our foursome this month are indeed among the smallest of all the constellations, but among the most rewarding for exploration by the visual observer.

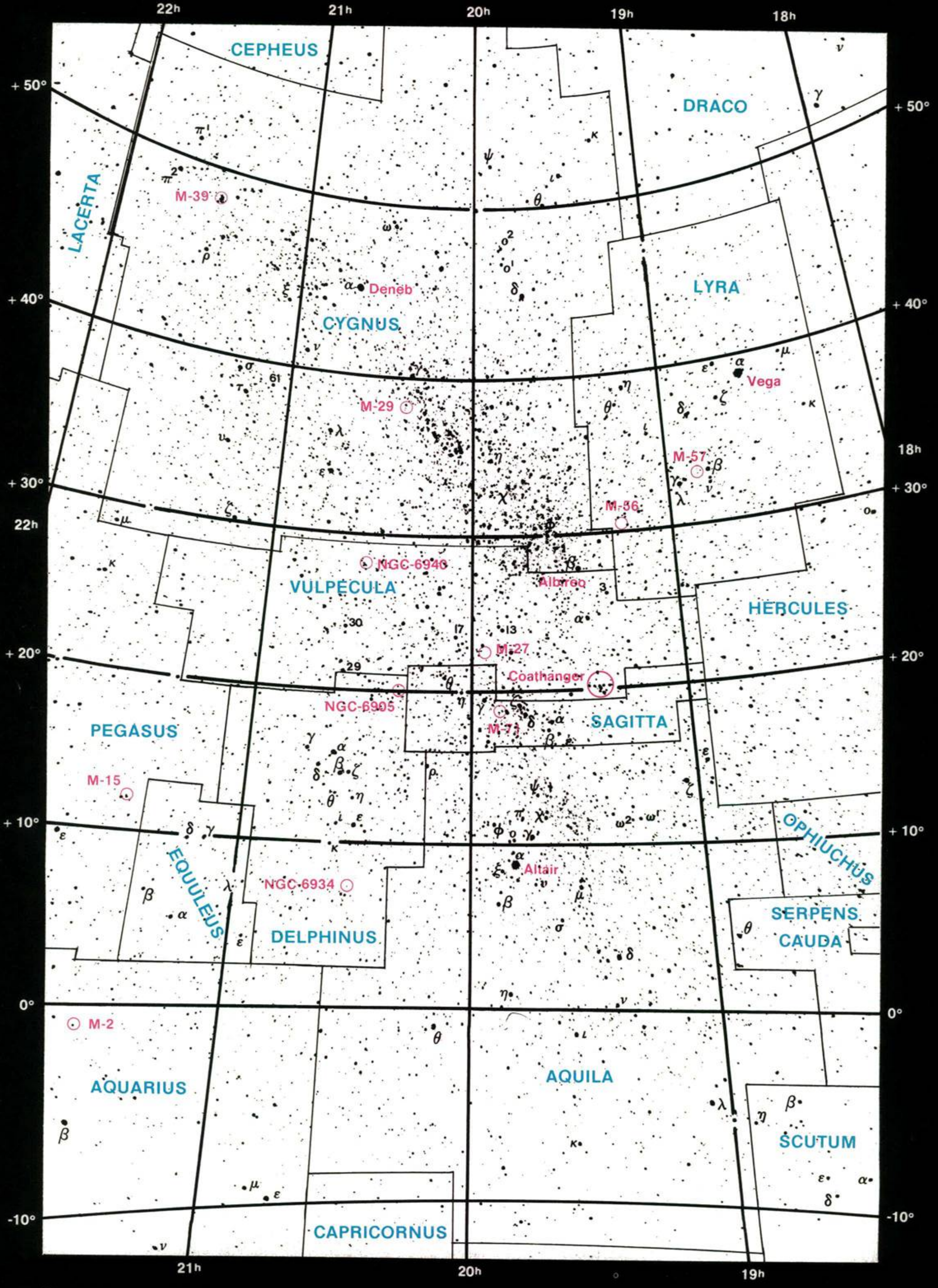
Field glass duos and combos abound here. Among these are Gamma (γ) Equulei, called a "striking pair" by Webb, and Alpha (α) Delphini, which he noted as a "fine combination; pale yellow, pale lilac". Yet another wide double is Alpha Vulpeculae (whose components are sometimes labeled 6 and 8 Vulpeculae in star atlases). Webb saw them as "deep and pale yellow, in a beautiful field three degrees nearly south from Beta Cygni (Albireo)." All of these objects are fine sights in tripod-mounted or steadily held 7 x 50 binoculars.

Striking groupings of suns are commonplace in this month's region; the most famous of these is Collinder 399 — sometimes called Brocchi's cluster. A line from Albireo south through Alpha Vulpeculae points to it. Better known as the Coathanger because of its distinctive shape, this clump of suns is marked by the stars 4, 5 and 7 Vulpeculae. Together, they are visible to the unaided eye as a nebulous patch of light.

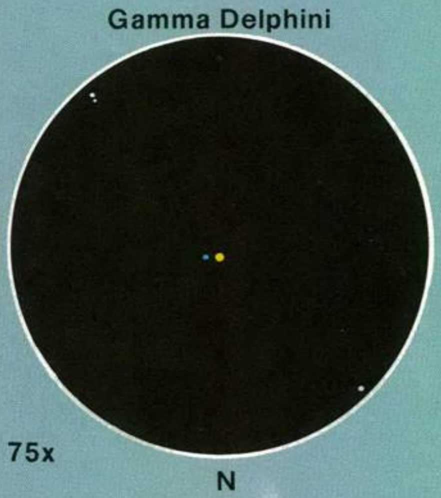
Webb called this group a "remarkable little asterism, as seen with an opera glass; six stars in a line". From the center of this line curves a chain of four stars, forming the "hook" of the hanger. In a four inch RFT at 15 power, with a field of four degrees, this is one of the most unusual sights in the entire sky.

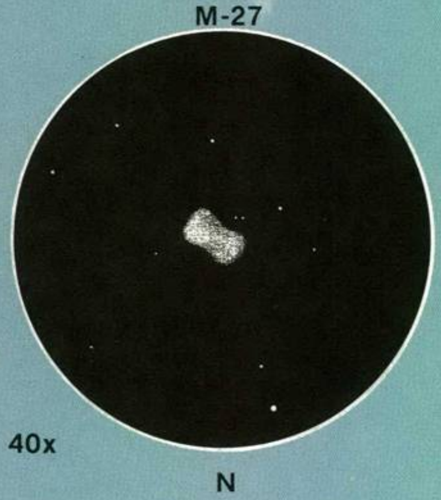
Even some of the unattached single stars here are lovely objects in themselves. Webb, for example, pointed out that 15 Sagittae "commands




22h
21h
20h
19h
18h
+ 50°
+ 40°
+ 30°
+ 20°
+ 10°
0°
-10°
22h
18h
21h
20h
19h
CEPHEUS
DRACO
LACERTA
LYRA
CYGNUS
Deneb
Vega
M-39
M-29
M-57
M-56
NGC-6940
VULPECULA
Albireo
HERCULES
M-27
Coathanger
NGC-6905
M-71
SAGITTA
PEGASUS
M-15
EQUULEUS
OPHIUCHUS
NGC-6934
Altair
SERPENS CAUDA
DELPHINUS
M-2
AQUARIUS
AQUILA
SCUTUM
CAPRICORNUS

Photograph by Brad Wallis and Robert Provin/Map by Henry J. Phillips another fine group. North, a little preceding (west), at a few minutes' distance is a seventh magnitude beautiful sapphire blue" star. These two objects comprise still another binocular double, located three degrees south of Eta (η) Sagittae. Patient scrutiny, preferably with the increased light grasp of a telescope, will reveal the icy blue cast of Webb's solitary sun.





Top: Gamma Delphini is a binary star with color contrast as striking as that of nearby Albireo in Cygnus. Gamma's brighter component is a gold star of magnitude 4.5, while its dimmer companion (magnitude 5.5) is greenish or bluish. The colors can be seen easily in a three inch refractor at 75 power as shown in our drawing, which has a field of view of about 45 minutes of arc. Bottom: Through a four inch reflector at 45 power, the twin connected blobs of light that make M-27 the Dumbbell nebula are easily seen. Compare this drawing with our cover photograph, or with the drawings of other planetary nebulae in this month's Gazer's Gazette. The field of view here is slightly more than one degree. Drawings by James Mullaney.

Gamma (γ) Delphini

Turning our attention now to some of the telescopic wonders of this month's region, we begin by inspecting one of the loveliest double stars in the heavens. This is Gamma Delphini, situated in the dolphin's nose. Here we find 4.5 and 5.5 magnitude gems, 10 seconds of arc apart.

Gamma's tints are marked; nearly all observers see the primary as golden yellow, and the companion greenish or blue-green. Strangely, Sir William Herschel recorded both stars as white in 1779, and Struve suspected that changes have occurred. Among the color combinations given by observers of the 1800s, we find white and yellowish, reddish yellow and greyish lilac, gold and flushed gray, and yellow and light emerald or pale green. Today the hues seem unmistakable to a trained eye. The actual spectral types of the primary and companion are K1 and F6, respectively, and the two suns form a slow moving binary system some 110 light-years distant.

Barns described this object as a "rich duo, gold-green"; Olcott called it "yellow, bluish-green, a beautiful object", and Muirden wrote, "yellow and turquoise; a charming pair". It is all of these and more! As our drawing with a three inch refractor at 75 power indicates, Gamma Delphini is a superb sight in small telescopes!

Our sketch also shows another double in the same field, to the southwest of Gamma. This is Struve 2725, a seventh and eighth magnitude duo about five seconds of arc apart. The pair looks like a reflection or ghost of the brighter object, and is sure to surprise you when you see it for the first time.

Gamma Delphini seems like an old friend to double star lovers — one to which you can turn time and again to delight your senses. If you haven't yet made its acquaintance, you have a very real thrill awaiting you the next clear night!

Epsilon (ϵ) Equulei

Our next stop takes us from stellar twins to a triplet — Epsilon Equulei, shining alone and visible to the unaided eye, west of Alpha Equulei near the Delphinus border. Compared to the tints of our first object, this one looks anemic — but has an attraction all its own.

This system consists of two sixth magnitude stars slightly less than one second apart, together with a seventh magnitude one an easy 11 seconds distant. The close pair is a binary having a period of just about one century. At its present separation, you should be able to see all three suns in four to six inch telescopes at high power on a steady night.

Among the colors given for Epsilon's components are yellow, blue or bluish lilac and dull white, and yellowish, yellowish and ashy white or blue. These hues are very subtle, and all three stars may appear a nondescript off-white to many observers. Webb called the close pair an "interesting and beautiful binary".

At *periastron* (closest approach), the sixth magnitude suns close to within 0.2 seconds of each other, and at such times lie beyond the reach of most smaller telescopes. Thus, to some generations of observers in the past, Epsilon has appeared as a double rather than a triple star! Even today this may still be the case, depending on seeing conditions and the size of your telescope. Why not check out this interesting case of stellar "split personality" yourself the next tranquil night?

M-71

Our third offering is a cluster of stars presenting several puzzles to the visual observer. This is M-71, easily found in small telescopes as a

Selected Objects — Vulpecula/Sagitta/Delphinus/Equuleus Region

Object	Type	Mag.	Size/ Sep.	R.A. (1950)	Dec.
VULPECULA					
* M-27	PN	7.6	8' x 4'	19^h57^m	+22°35'
NGC-6940	OC	8.2	20'	20^h32^m	+28°08'
SAGITTA					
* M-71	GC	6.9	6'	19^h52^m	+18°39'
θ(Theta)	★3	6.3,8.7,7.1	12", 78"	20^h08^m	+20°46'
DELPHINUS					
* NGC-6905	PN	10.5	44" x 37"	20^h20^m	+19°57'
NGC-6934	GC	9.2	1.5'	20^h32^m	+07°14'
* γ(Gamma)	★2	4.5, 5.5	10"	20^h44^m	+15°57'
EQUULEUS					
* ϵ(Epsilon)	★3	5.9,6.2,7.1	1" 11"	20^h57^m	+04°06'
λ(Lambda)	★2	7.4, 7.4	3"	21^h00^m	+06°59'

* Detailed in Close-Up

★2,3 = Double or Triple Star
PN = Planetary Nebula
OC = Open Cluster
GC = Globular Cluster
Mag. = Magnitude
Sep. = Separation

hazy patch nestled midway between Gamma and Delta (δ) Sagittae in the shaft of the arrow, very near the sixth magnitude star 9 Sagittae.

M-71 is classified as a seventh magnitude globular cluster some six minutes of arc in apparent size — and so it looks to most at the eyepiece. There are uncertainties here, however. Some sources say it is as faint as ninth magnitude, while others omit a magnitude listing entirely! Holyoke tells us this object is "classified as a globular cluster but rather irregular in form", and Norton claims "usually classed as a rather condensed galactic (open) cluster." Like M-11 in Scutum, M-71 may be intermediate in form between the open and globular types — another case of split personality!

In three and four inch telescopes at about 45 power, M-71 has a nebulous appearance at first glance. However, closer inspection shows it as a granular cloud of stars, and at 75 power or more it is obviously a concentrated cluster. Careful focusing is essential in resolving the hosts of stellar pinpoints in such beehivelike objects! In the case of M-71, the sixth magnitude star beside it is ideal for this purpose.

If you have a small telescope, you might like to judge the cluster's magnitude for yourself by comparing it to an out of focus star image of known brightness — much as is done for comets. If you have a six inch or larger instrument, try recording your visual impression of its structure. Does it look like a rich open cluster or a loose globular to you?

Webb described M-71 as "large and dim, hazy to low powers with 3.7 inch (refractor), yielding a cloud of faint stars to higher magnifiers". Barns saw it as a "dazzling sweep of starclouds!" in his 10 inch reflector.

Both Webb and Olcott remarked about a beautiful low power field, containing pairs and triples, about one degree south of M-71 itself. This is officially recognized as an open cluster and is designated H-20 ("H" for Harvard). Listed as 9.6 magnitude, it is 10 minutes of arc in diameter and contains about 20 stars. As such, it is considered loose and poor for its class. Careful attention is required to distinguish it from the rich Milky Way background here.

The two clusters are not associated, for H-20 is a relatively near "foreground" object, while M-71 lies 18,000 light-years from us in the depths of galactic space. Although not a real "showpiece", its strange unearthly glow may keep you at the eyepiece half the night!

NGC-6905

For those of you who enjoy tests of your observing prowess, we suggest having a go at our next object. This is NGC-6905, an obscure planetary nebula hidden in a starry triangle. Careful sweeping with six inch and larger scopes at 50 to 100 power will show it on a dark night, situated four degrees due east of Eta Sagittae. The nebula is located across Sagitta's border, in Delphinus.

NGC-6905 shines at visual magnitude 10.5, and spans an area 44 by 37 seconds of arc size. Webb logged it as "small, faint, misty, ill-defined, closely surrounded by several small stars." As telescopic aperture increases, this object becomes impressive. In 10 and 12 inch reflectors at 80 to 150 power, its eerie blue to sea-green disk is seen beautifully framed in sparkling stars.

In its terse notation, the NGC rates this nebula "!!" which translated means "remarkable — very much so". It was the 16th discovery in William Herschel's Class IV, planetary nebulae. Lord Rosse thought it looked spiral in form in his large reflectors, while photographs show it to have a mottled structure and a 14th magnitude central star.

Like most of the small members of its class, NGC-6905 "blinks out" when stared at directly and can only be seen well using averted vision. This unique property provides a useful technique for distinguishing a tiny planetary nebula from the surrounding star background at sweeping powers. Higher magnification will then confirm the presence of a nebulous disk.

NGC-6905 lies more than 7,000 light-years away, embedded in the rich stratum of the Milky Way. Most observers seldom visit it in their nightly excursions. Why not pay it a visit the next clear night?

M-27

Should NGC-6905 disappoint you, our final offering — also a planetary nebula — is guaranteed to thrill and delight you! This is M-27, the famous Dumbbell nebula in Vulpecula. It lies at the corner of a large rectangle in the sky, formed with the stars Beta, Gamma and Epsilon Cygni. It can also be found seven degrees due north of Gamma Sagittae. Visible in a good finder, it's readily swept up with a low power eyepiece.

This magnificent object shines softly at magnitude 7.6, and is truly enormous for its class — 480 by 240 seconds, or eight by four minutes in extent! It has a faint 13th magnitude central star which is difficult to identify because of the Milky Way's rich overlay. In a four inch reflector at 40 power, M-27 looks like a puffy white cloud drifting through a star filled night sky, as hinted in our drawing. A noticeable pinch near the middle gives it a pincushion appearance and results in its famous name.

Considered by far the easist and most conspicuous of all the planetaries, M-27 has received considerable attention from visual observers and is a favorite subject of astrophotographers. Some, in small instruments, view it as two hazy patches in contact. It looks like its namesake in medium sized scopes; larger apertures begin to fill up the "pinches", and a complete disk can be made out in large observatory telescopes. Even in these, however, the dramatic colors seen in photos are not obvious.

M-27's shape was likened by Muirden to the rough form of a cotton reel or spool. Lord Rosse's huge 72 inch metal mirror reflector showed the nebula surrounded by an external ring having a neck like a laboratory retort!

Webb's impression of the Dumbbell was: "In a rich field we find two oval hazy masses in contact, of which the preceding seems to me the brighter, as it did to Herschel. His reflector failed to resolve it, but showed the dark notches (which . . . are usually represented too deep) filled in and made protuberant by faint luminosity, converting the whole figure into an ellipse." Pickering included it in his roster with the comment "obviously a double condensation, but bearing little resemblance to its prototype".

Probably the most inspired account of M-27's visual appearance was made by Barns: "Giant 'Dumb-bell', so-called on account of its resemblance with low powers; but with higher magnnification the likeness vanishes, as is the case of most celestial analogies to terrestrial commonplaces. Faint nucleus, many stars enmeshed like pearls caught in swirls of lace. Planetary stage of nova of remote ages."

Words simply fail, however, to adequately convey the overpowering beauty of celestial showpieces like M-27. They are but the secondhand narrative of the cosmic traveler — much like hearing accounts of distant and exotic lands as compared to actually visiting them yourself. No description or photograph can ever match the thrill of seeing such glories with your own eyes at the telescope.

Some 3,500 light-years away, the Dumbbell nebula floats serenely through the sky like some heavenly pillow on a star studded bed. Here indeed is rest for a weary soul — one of the many very real benefits that attends stargazing. Realizing this, it's easy to understand feelings like that expressed by noted California observer Malcolm Thomson: "Deep sky observing is more than just a hobby, it is an important part of my life."

CLOCKWISE FROM ABOVE:

Owl at 20 feet
Celestron 750mm, f/6

Rose at 15 feet
Celestron 750mm, f/6

Peacock at 50 feet
Celestron 750mm, f/6

Orion Nebula
Celestron 8

Rings of Saturn
Celestron 14

Squirrel at 75 feet
Celestron 1250mm, f/10

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The basic Celestron 8, shown here on equatorial wedge and tripod.

Beyond the front end of a Celestron Telescope lie entirely new worlds — bigger, brighter, sharper, more detailed worlds.

Our sunlit Earth — marvelous in its intricacy, overwhelming in its color, profound in its immediacy. And worlds beyond — in a universe of majestic proportions and breathtaking beauty. A universe where planets roam the outer reaches of our solar system and their moons shuttle to and fro. Where great spheres of stars — light-centuries in diameter — ride loftily above the disk of our galaxy. Where remote clouds of gases cast their eerie filamentary glow onto the waters of infinity.

These are the worlds we offer.

And next week at this time, you could have in your hands the means to explore them.

-DEALERS-

Inspect Celestron products (binoculars, telephoto lenses and telescopes) at our authorized dealers. See inside ad in this issue for dealer listing.

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Celestron

Bringing Man and Nature Closer Together